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UNATTENDED GROUND SENSORS
AND
PRECISION ENGAGEMENT

by
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Unattended ground sensors (UGS) are devices that automatically gather sensor data on a remote target, interpret the data and communicate information back to a receiver without interaction with a human operator. The objective of this thesis is to determine how unattended ground sensor technologies might support precision engagement. Comparative case analysis of the use of sensors in Vietnam, the Sinai and Iraq is used to develop principles that UGS must meet to support precision engagement. This study finds that precision engagement requires long endurance UGS to be delivered covertly to discriminate between targets, interrogate them for emissions, while disseminating a fused picture of the target. This study details roles and missions which UGS can fill as well as their costs, benefits and unintended consequences.

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UNATTENDED GROUND SENSORS AND PRECISION ENGAGEMENT

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ABSTRACT

Unattended ground sensors (UGS) are devices that automatically gather sensor data on a remote target, interpret the data and communicate information back to a receiver without interaction with a human operator. The objective of this thesis is to determine how unattended ground sensor technologies might support precision engagement. Comparative case analysis of the use of sensors in Vietnam, the Sinai and Iraq is used to develop principles that UGS must meet to support precision engagement. This study finds that precision engagement requires long endurance UGS to be delivered covertly to discriminate between targets, interrogate them for emissions, while disseminating a fused picture of the target. This study details roles and missions which UGS can fill as well as their costs, benefits and unintended consequences.

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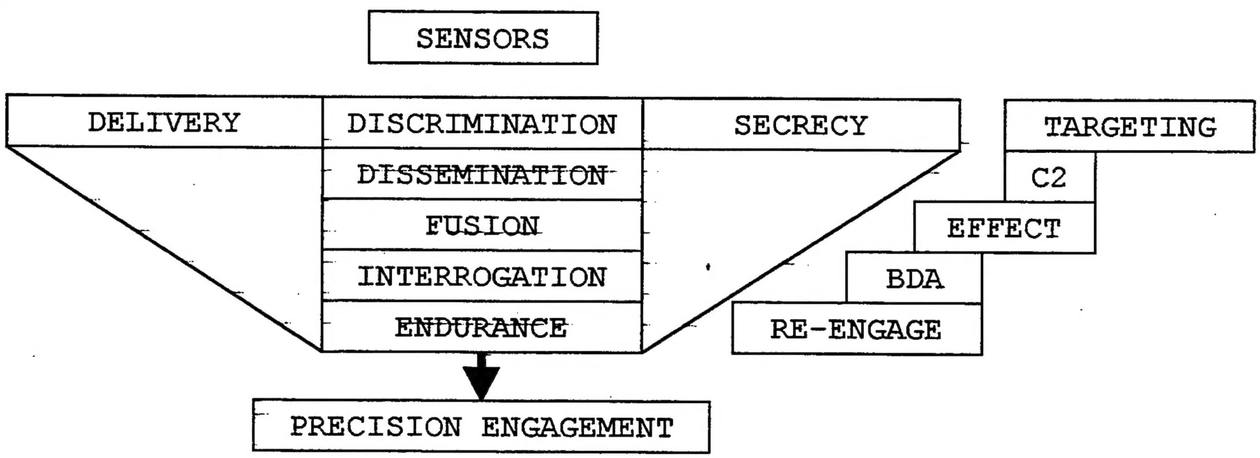
EXECUTIVE SUMMARY

Unattended Ground Sensors (UGS) are devices that automatically gather sensor data on a remote target, interpret the data and communicate information back to a receiver without interaction with a human operator. Historically, UGS technology consisted of sensors which had a short range, operated on a continuous basis, focused on acoustic or seismic detection and had a short operational life span. These technological constraints led to the development of a defensive paradigm. Currently the US military is exploring the use of UGS technology in the offense, as part of its *revolution in military affairs (RMA)*. A key element of the RMA is the pursuit of *precision engagement*. This term summarizes the US military's goal of leveraging information technologies to improve its ability to detect and destroy enemy forces.

The primary objective of this thesis is to determine how unattended ground sensor technologies and tactics might support *precision engagement*. The study begins by defining the requirements of precision engagement. These requirements are ***targeting***, command and control (***C2***), achieving a desired ***effect***, bomb damage assessment (***BDA***) and the ability to ***re-engage***. These five requirements when applied to historical

case studies are used to develop principles which sensors must meet to satisfy precision engagement.

This study finds that precision engagement, requires long **endurance** sensors to be **delivered covertly** to **discriminate** between targets, **interrogate** them for emissions, while **disseminating** a **fused** picture of the target. This examination uses these principles as benchmarks from which to compare and analyze the ability of any sensors (air, ground or space based) to support *precision engagement*.



Precision engagement, requires long **endurance** sensors to be **delivered covertly** to **discriminate** between targets, **interrogate** them for emissions, while **disseminating** a **fused** picture of the target

A methodology of comparative case analysis of UGS in Vietnam and the Sinai is used to evaluate the principles. A Desert Storm case study of air and space sensors is then used as a "tough test" to define the gap between what air

and space sensors can provide, what is needed for *precision engagement*, and how UGS can fill the "sensor gap."

This study details roles and missions which UGS can fill as well as the costs, benefits and unintended consequences of their use. The results indicate two roles for ground sensors. First, UGS may substitute for other systems. This could achieve an economy of force enabling a high-cost or limited air or space sensor to focus on other missions. UGS may also be used as a substitute for highly classified sensors enabling sensor information and technology to be shared with a coalition partner. A second role for UGS is as a complement to other systems. In this role UGS would be used to provide a capability air and space sensors cannot or as a force multiplier to augment other sensors. This would support specialized missions requiring specific intelligence, an ability to speed detection and targeting, or to enable force projection of a tactical military intelligence capability. However, the use of UGS to reduce the "fog of war" may enable even greater benefits to be achieved. These benefits are "tailor to task" forces and reduced basing requirements.

The greatest cost of using UGS is not defined by monetary concerns or research and development. Instead, the cost of UGS is measured by the risk of casualties and mission compromise. While artillery and UAV delivery methods

are being developed for UGS, this study finds them to be ineffective in supporting the deep battle. This study finds that UGS delivery can be best accomplished by Special Operations Forces.

A detailed examination of unintended consequences is included to address the dangers and risks associated with UGS and how to mitigate these problems. Unintended consequences such as a "technological My Lai," bandwidth overload, "Privates War," spoofing, EMP weapons and others are addressed. This study concludes with a prescription for the future development and employment of unattended ground sensors.

I. INTRODUCTION

What enables the wise sovereign and the good general to strike and conquer, and achieve things beyond the reach of ordinary men, is foreknowledge.

-Sun Tzu, *The Art of War*

Unattended Ground Sensors (UGS) are devices which, when placed on the ground, automatically gather sensor data on a remote "target," interpret the data, and communicate information back to a receiver. UGS gather and interpret data without interaction from a human operator or physical contact with a target. Instead, UGS "sense" targets by monitoring their emissions. Types of emissions include acoustic, seismic, electro-magnetic waves (optical, infrared, ultraviolet), electro-magnetic fields, chemical and nuclear radiation. [1] Historically, UGS technology consisted of sensors which had a short range, operated on a continuous basis, focused on seismic or acoustic detection, and had a short operational life span. These sensors required air delivery or emplacement by hand and frequent replacement due to the short life span of their battery power. These technological constraints resulted in the

[1]Hamrick, R., Peglow, S., Sleefe, G. (1997). Application of Unattended Ground Sensors to Stationary Targets. In G. Yonas (Ed.), Peace and Wartime Applications and Technical Issues for Unattended Ground Sensors. Proceedings of SPIE Vol. 3081, 21-29.

development of a *defensive paradigm* in which UGS were associated strictly with defensive operations. In this capacity, sensors were typically used to monitor the "front lines" or the perimeter of friendly positions to obtain early warning of an attack.

Currently, the US military is exploring the use of UGS technology as part of its,"Revolution in Military Affairs."[2] This revolution relies on information technologies to support warfighting. "Precision Engagement" is the term that summarizes the US military's goal of leveraging information technologies to dramatically improve its ability to detect and destroy enemy forces. *Joint Vision 2010* defines *precision engagement* as a "system of systems" that will enable US Military forces to "locate an objective or target, provide responsive command and control, generate [a] desired effect, assess [the] level of success, [while] retaining the flexibility to reengage with precision when required." [3] When the definition of precision engagement is dissected into its component parts, five requirements emerge. These requirements are ***targeting,*** command and control (***C2***),

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[2] Michael Roberts, a Swedish military historian coined the term in the 1950s. He writes that a revolution in military affairs is defined by changes in force structure, changes in the complexity of tactics, changes in strategy, and the impact of military technology on social, political, and economic factors.

achieving a desired ***effect,*** bomb damage assessment (***BDA***) and the ability to ***re-engage***.

With these five requirements in mind, what criteria must a sensor meet in order to support precision engagement? For targeting, sensors must be *delivered* to a location where they can sense the target. They must be *covert* to prevent the enemy from innovating around the sensor or destroying them. Sensors must also be capable of *discriminating* between a variety of targets to support different types of operations while developing a coherent picture of enemy forces on the battlefield. (See Figure 1.1)

The second requirement is command and control (C2). Command and control has only one criteria: *dissemination.* Commanders must manage a large and diverse amount of information. The ability to disseminate it in real time to the right commander or force is essential to the conduct of a mission.

Third is the ability to achieve a desired effect. This is not restricted to the sensor itself but encompasses accurate targeting, the size and type of force allocated to the mission, and the type and quantity of munitions expended against a target. In order to facilitate these requirements, various types of sensor data must be *fused* together to

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[3] Department of Defense (1997). Joint Vision 2010. GPO, Washington, DC. p21

provide a complete picture of the target and the battlefield.

The fourth requirement is bomb damage assessment. Was the desired effect achieved? Sensors support BDA by *interrogating* the target for indications of life or death. This can be accomplished by observing the targets actions or signature relative to a functioning target or previous sensing of the same target.

The final requirement is the ability to re-engage when required. Invariably some targets will have escaped destruction or have sustained incremental damage, which allows them to continue operating. This necessitates the ability to conduct a follow on strike of the same target. Central to this requirement is the endurance of a particular sensor. If it can operate 24 hours a day, every day, then it can support targeting, command and control, and BDA for a second strike.

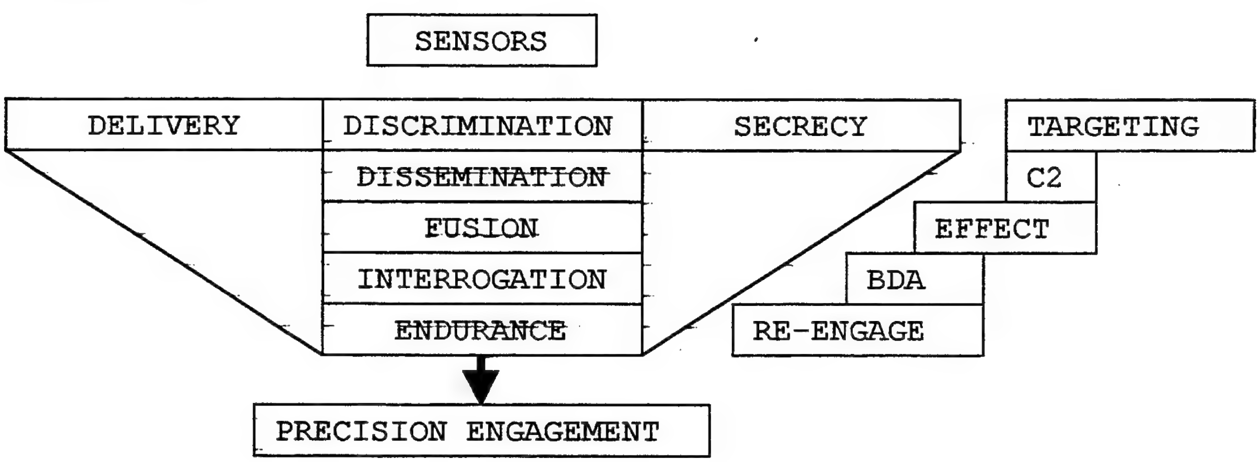

Figure 1.1
Sensor Criteria for Precision Engagement

Precision Engagement in short, requires long **endurance** sensors to be **delivered covertly** to **discriminate** between targets, **interrogate** them for emissions, while **disseminating** a **fused** picture of the target. This study uses these criteria as benchmarks from which to compare and analyze the ability of any sensors (air, ground or space based) to support *precision engagement.*

A. PURPOSE

The primary objective of this thesis is to determine how unattended ground sensor technologies and tactics might support *precision engagement.* A secondary purpose is to acquaint the reader with the rapid advancements occurring in UGS technologies. UGS are increasingly approaching the condition described by "Moore's Law." [4] Just as computers double their computing power every two years at the same cost, so will the capabilities of UGS. This study will demonstrate that with the increase in UGS capabilities, they can effectively support the conduct of *precision engagement.* This study will detail roles and missions which UGS can fill

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[4] Gordon Moore, co-founder of Intel, accurately predicted in 1965 that every 18-24 months, a new computer memory chip would be invented which would have double the processing capacity of its predecessor at the same cost.

and their associated costs, benefits and unintended consequences.

B. RELEVANCE

In the wake of Desert Storm, the US military has begun to recognize that its air and space-based sensors are not adequate to support "detection, identification, targeting, and post-strike assessments of time-critical (including mobile) and underground targets."[5] In response, the US military has begun to study the use of unattended ground sensors to mitigate these deficiencies. Use of sensors in this role is gaining attention due to advancements in sensor technology, which have produced "sensors that are smaller, stealthier, cheaper, smarter, more power efficient and more communicative." [6] Recognition that sensors have the potential to act as a substitute for high cost and limited air and space assets is also a factor in their popularity.

C. METHODOLOGY

This study will use comparative case analysis of the use of unattended ground sensors in Vietnam and the Sinai. These cases were selected because they demonstrate the use of UGS in both war and peace, as well as protracted and

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5 Yonas, G. (Ed.) (1997). Peace and Wartime Applications and Technical Issues for Unattended Ground Sensors. Proceedings of SPIE Vol. 3081, ix.

6 Ibid., p. ix.

contingency applications. Other cases involving the use of UGS were available but were not selected for this study. The use of UGS by the US Border Patrol along the northern and southern borders of the United States and the use of UGS by the US Army in the Demilitarized Zone (DMZ) in Korea are examples. These cases are not addressed because the lessons that these cases would provide are clearly evident in Vietnam and the Sinai. Addition of these cases would have added greater corroboration but not greater explanatory power.

While the Vietnam and Sinai cases contain a wealth of information about the successes and failures of ground sensor tactics and technology, the Desert Storm case study is concerned with air and space based sensors. This case study is critical to an examination of ground sensors because it acts as a "tough test." This case study demonstrates that the US Armed Forces failed to achieve *precision engagement* because of the limitations of air and space sensors. These limitations resulted in a "gap" between what was available and what was desired to acheive precision engagement. The tough test is to determine whether UGS could have filled this "sensor gap."

The data and lessons learned from the historical use of UGS, emerging concepts of precision engagement and the "sensor gap" will be integrated in the final chapter. This

will culminate in a prescription for future development and employment of UGS.

One might ask, why is this study based entirely on US cases? The answer is simple. During my research only one other case involving UGS appeared. This case involved the use of UGS by British forces to monitor the partitioning of Catholics and Protestants in Ireland. Little if any information was available and what I did find was a mirror image of the use of UGS by the US Border Patrol.

Finally, this study is based entirely on unclassified sources and information. I obtained my information from newspaper articles, books, unpublished papers, speeches and reports by the participants of operations in Vietnam and the Sinai, many of which were obtained from the National Archives. In each case, I attempted to find a first person source for my information or to find at least three sources which were in agreement on the same point. This was especially difficult when developing the Desert Storm case study. Extremely little information is available concerning satellite capabilities and technology due to their classified status. In this case I based my study on open source books and publications which are considered to be accurate enough to be used as textbooks at military universities and military intelligence courses. I believe that based on an open source research and analysis, the case

studies of Vietnam and the Sinai are extremely accurate and the Desert Storm case is sufficiently accurate to enable a worthwhile comparison without compromising any technological capability.

D. SCOPE OF THE STUDY

This study will not attempt to examine commercial uses of UGS. An analysis of this type would require a separate examination to study this issue adequately. However, this thesis will address air and space sensors. This will be done to demonstrate the difference in roles and capabilities of UGS and other sensors. It will also demonstrate that there is currently a gap between what air and space sensors can provide and what is required for precision engagement. Analysis of air and space sensors is also important because they have a symbiotic relationship with UGS. Many UGS rely on satellite or airborne platforms to receive, analyze, or retransmit data to another station. Finally, this comparison will show how UGS provide a capability that enables them to complement or substitute for air and space sensors.

E. RESEARCH DESIGN

Figure 1.2 is a visual flowchart of the research design of this thesis. This flowchart depicts the relationship between the central themes of the study and subordinate

hypotheses. The design of this research is based on the assumption that few readers have been exposed to UGS technologies and their tactics.

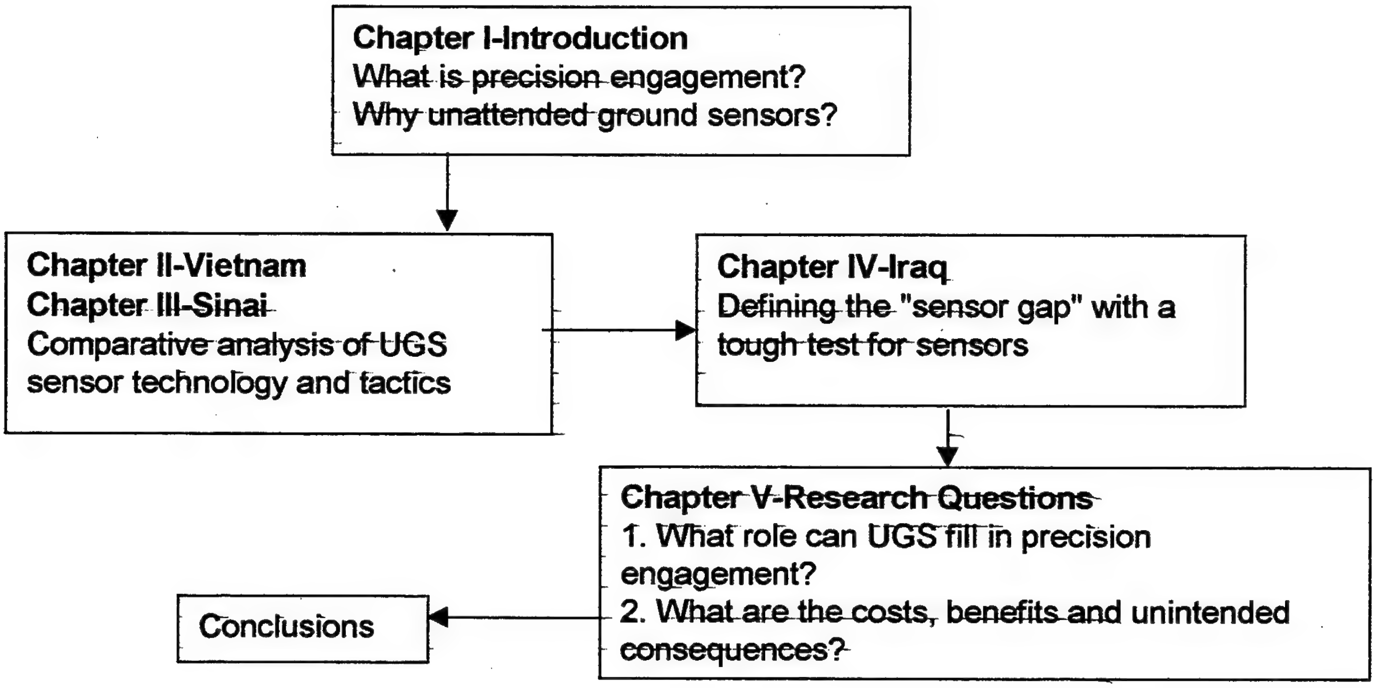

FIGURE 1. 2 RESEARCH DESIGN SCHEMATIC

1. Chapter I Introduction

The purpose of this chapter is to introduce the information warfare concept of precision engagement(PE) and explain the value of integrating PE and ground sensor technology. Principles of PE and UGS are defined to establish benchmarks for comparing historical uses of UGS tactics and technology, their connection to PE and how they are different from air and space sensors. This chapter also

explains the methodological underpinnings of the study and a general road map of the research process.

2. Chapter II Low Intensity Conflict

Vietnam is a study in the development of sensors on the automated battlefield. It demonstrates the use of sensors in low intensity conflict and also marks the first use of sensors in combat by ground forces. Before Vietnam, sensors had been successfully used by the US Navy in anti-submarine warfare (ASW). Unattended ground sensors had also been developed as part of what was then a top secret operation called TACIT in Korea. However, the sensors arrived in Korea in 1954, just after the cessation of hostilities. The Navy and TACIT sensors provided the start point in Vietnam. The use of UGS in Vietnam is also significant because it nearly achieved a *revolution in military affairs* (RMA). It did not achieve a complete revolution because the proponents of sensor warfare overestimated the pace of technological change that would enable sensors to become more efficient, and more cost effective. However, Vietnam does serve as a treasure trove of ideas and lessons about sensors, precision engagement, and information warfare. Many of these lessons are still relevant today.

3. Chapter III Regional Confidence Building

A study of the Sinai demonstrates the value of sensors in promoting peace. While sensors in Vietnam were used by

military forces for *precision engagement,* sensors in the Sinai were used by the US State Department for peacekeeping. Many of the same lessons learned from Vietnam are also present in the Sinai corroborating the value and relevance of previously learned lessons. While the Sinai did not return to open warfare, the sensors did provide precise locations of activity within the confines of the Disengagement Agreement. While the current military concept of sensors and Information Warfare focuses on attacking and destroying targets, this case study demonstrates their use in *Military Operations other than War* (MOOTW).

4. Chapter IV High Intensity Conflict

In the Gulf War, there was a great deal of remote sensing and precision engagement conducted. However, it was conducted in the absence of unattended ground sensors. Sensing was conducted primarily by satellite and air surveillance aircraft. My purpose in this chapter is to identify what failures occurred because of an over-reliance on air and space based sensors. From these failures I will then identify what gaps in precision engagement could have been filled by UGS.

5. Chapter V Research Questions

The purpose of this chapter is to integrate historical lessons learned and the concept of precision engagement to identify what roles and missions UGS can fill. This chapter

will provide an analysis of the costs, benefits and unintended consequences of making these changes. This will be used to develop a prescription for the future of UGS and *precision engagement*.

II. VIETNAM

It is pardonable to be defeated, but never surprised

-Frederick the Great

A. INTRODUCTION

Vietnam is a study in the development of sensors on the automated battlefield. It demonstrates the use of sensors in Low Intensity Conflict and marks the first use of Unattended Ground Sensors in Combat. The use of sensors in Vietnam did not achieve a revolution in military affairs because it did not achieve the success necessary to alter the way in which the US military or other nations conduct war. This is primarily because the proponents of the sensors over-estimated the pace at which technology would advance. However, it does provide a wealth of lessons about sensors and precision engagement. It also provides many insights into the costs, benefits, and unintended consequences that may develop as a result of sensor-based warfare. These lessons have largely been forgotten despite their relevance today

B. BACKGROUND

In the mid-1960s the United States Air Force was heavily engaged in a protracted bombing campaign against North Vietnam. Its purpose was to coerce or compel the North

Vietnamese government to end their support for the insurgency in South Vietnam. By early 1966, it was apparent to Secretary of Defense McNamara that the strategic bombing campaign was having little effect on North Vietnam. The Ho Chi Minh Trail, which was used by the North Vietnamese to funnel supplies and soldiers into South Vietnam, continued to be used despite the bombing. In fact, the pace of infiltration and the quantity of supplies were increasing. This led a number of military planners to seek an alternative solution. One of the more prominent ideas was borrowed from the French experience in Algeria. In the late 1950s, the French had achieved some success in blocking Tunisian infiltration into Algeria using a barrier.[7] The barrier consisted of barbed wire, land mines and a variety of listening devices. The idea of creating a barrier between North and South Vietnam was often studied by US military planners but never implemented. It was assumed that communist infiltration could be stopped through strategic bombing.

In January 1966, Roger Fisher of the Harvard Law School sent a memo to Assistant Secretary of Defense John

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[7] Baldwin, H. (1967, July 21). US Adding 12 Miles to Vietnam Barrier Strip. New York Times, p. 2.

McNaughton advocating the establishment of a barrier. [8] While this was not a new idea, its timing was perfect as many in the Defense Department were searching for alternatives to strategic bombing. Fisher's particular concept envisioned a barrier "about 10 miles wide and 160 miles long [that] would be flanked on either side by a wide defoliated free-fire zone." [9] McNaughton passed the memo to Secretary of Defense McNamara. McNamara showed great interest in the idea and requested input from his field commanders, one of whom was Admiral U.S. Grant Sharp, the commander-in-chief of Pacific Command. Admiral Sharp was opposed to the idea for a number of reasons. He believed that the barrier "would take up to four years to create, tie up seven or eight United States Divisions, strain the supply system, and probably not work after all." [10] Despite significant opposition to the idea, McNamara directed the army to continue studying the plan and to develop devices that would support it. At roughly the same time McNamara was asked by scientists from MIT and Harvard (known as the Jasons) if he would be interested in having them study a

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[8] Senator Gravel. (1971-72). The Pentagon Papers: The Department of Defense History of United States Decision Making on Vietnam. Boston, Beacon Press. p. 112.

[9] Dickson, P. (1976). The Electronic Battlefield. London, Indiana University Press. p 21.

[10] Ibid, p. 21.

variety of technological issues relating to the War in Vietnam. Given the desire to develop alternative solutions, McNamara readily accepted their offer.

1. JASONS

The Jasons were organized in 1959 by the Institute for Defense Analysis (IDA), which served as a strategic military think-tank. Their initial role had been concerned primarily with the study and development of nuclear weapons. The Jason Division or "Jasons", while associated with the IDA, "were primarily non-IDA scholars."[11] They consisted of approximately 45 of the best scientists that America's universities had to offer. The Jasons even boasted that their organization included several former Nobel Laureates. The Jasons were not a standing organization. Instead, they operated in an adhoc fashion, coming together each summer to study select problems related to military technology and national security. In the mid-1960s, these scientists would act as Secretary of Defense McNamara's leading scientific advisors.

The Jasons were first called into action concerning Vietnam to assess the effectiveness of the Rolling Thunder campaign in which the Air Force was conducting strategic bombing against the Ho Chi Minh Trail. The Jasons were asked

[11] Senator Gravel. (1971-72). The Pentagon Papers: The Defense Department History of United States Decision Making on Vietnam. Boston, Beacon Press. p. 115.

by McNamara to prepare a report detailing "technical possibilities in relation to our military operations in Vietnam" as their summer of 1966 project.[12] On April 26, McNamara amended his request and directed that the group also examine the development of a barrier. This barrier would be "[a] fence across the infiltration trails, warning systems, reconnaissance (especially night) methods, night vision devices, defoliation techniques, and area-denial weapons."[13]

In their report, the Jasons concluded that the strategic bombing campaign in Vietnam was largely a failure. It had not reduced the rate of infiltration. In fact, the Jasons argued that it might have served to strengthen the moral resolve and resistance of the North Vietnamese people to the United States. The bombing failed because North Vietnam was a country based on a subsistence economy. There was little industry to attack; instead, it was largely an agrarian society. Because of the inability of the US Air Force to destroy large economic, industrial and military targets, what damage was done could easily be absorbed by the economic support that North Vietnam was receiving from China and the USSR. This economic support combined with a high civilian death toll actually caused the North

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[12] Ibid, p. 115

[13] Ibid, p. 115

Vietnamese population to become more supportive politically and more dependent economically on their government. True to McNamara's request, the Jasons proposed an alternative solution in the form of a barrier separating North and South Vietnam. The barrier "would have two separate components: an antipersonnel barrier about 20 by 100 kilometers running across the southern edge of the DMZ and into the Laotian panhandle, and an anti-vehicular barrier that would be twice as wide but just as long." [14] Central to the proposed barrier was the inclusion of a wide array of advanced sensors, which would pinpoint attempts by the North Vietnamese to infiltrate through the barrier. These sensors would "provide for ground troops the kind of early warning systems that we long have provided in anti-submarine warfare and in air defense." [15]

The Jasons delivered their report criticizing the *Rolling Thunder* campaign and proposing a barrier to McNamara. This indictment of the current military campaign and its proposal for new tactics and technology was viewed as highly sensitive and classified. Within seven days of receiving the report, McNamara began discussions with the Joint Chiefs of Staff and senior leadership in Vietnam.

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[14] Dickson, P. (1976). The Electronic Battlefield. London, Indiana University Press. p. 26

[15] Beecher, W. (1970, February 13). Sensor Seal Around Vietnam Studied. New York Times, p. 10.

A majority in favor of the barrier was achieved despite Admiral Sharp's objections.

2. Defense Communications Planning Group

In September of 1966, McNamara appointed General Alfred Starbird as the action officer for the barrier. McNamara identified General Starbird, a former manager of the atomic energy test program as the best choice to develop a barrier that required both innovative technology and tactics. General Starbird was instructed to maintain a direct line of communications with Secretary McNamara on the progress of the barrier. The organization of the barrier team was called Joint Task Force 728 and was later given a non-descript name titled the Defense Communications Planning Group (DCPG). The name was intended to sound mundane and unimportant to discourage the enemy from taking an interest in it.[16] The group was headquartered on the grounds of the US Naval Observatory in Washington D.C. and was staffed with 170 personnel. The organization was created outside of the normal military chain of command but was given the authority to task the Joint Chiefs and other government departments to accomplish its mission.

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[16] During the Vietnam War, other organizations with highly classified missions were given similar non-descript names. The Army Special Forces elements that infiltrated North Vietnam, Laos and Cambodia, used the title of the Studies and Observations Group to shield their activities.

The Defense Communications Planning Group operated successfully for a period of five years before being disbanded near the close of the Vietnam War. It enjoyed billions of dollars in funds and had sponsorship from the highest levels of the United States Government. Members of the DCPG compared their service and experience as the near equivalent of the Manhattan project.[17] This was because "it allowed you to be in on the birth of an idea and see it move through all its stages-design, development, prototype, testing, production-and into combat in Vietnam in just about the fastest time which was less than a year in most cases."[18]

C. TACTICS

The initial tactics proposed by the DCPG were defensive, linear, and were intended to provide early warning of an attack against the "front lines" or the perimeter of a friendly position. This tactic was the original barrier plan and became known as the McNamara Line, which would separate North and South Vietnam. Other significant tactics would quickly follow; the 360-degree perimeter defense of Khe Sanh, which occurred in 1968, would

[17] The Manhattan Project was the title of a massive World War Two effort that developed the first Atomic Bomb.

[18] Dickson, P. (1976). The Electronic Battlefield. London, Indiana University Press. p. 33.

serve as one of the most successful applications of unattended ground sensors in combat. However, the greatest test of sensors would be a project known only as Igloo White. This project would tax the greatest minds of the DCPG to rapidly invent, produce and employ advanced sensors along the Ho Chi Minh Trail.

1. The McNamara Line

The "McNamara Line" was one of many names applied to the barrier effort during the Vietnam War. The purpose of the barrier was to seal off South Vietnam from North Vietnam and Laos. In the 1960s, soldiers and Marines had been fighting an elusive enemy that was infiltrating South Vietnam across the demilitarized zone (DMZ). They were also fighting an enemy that understood the American rules of engagement. US forces could not enter North Vietnam. However, North Vietnamese and Viet Cong guerrilla fighters habitually used the imaginary boundary to their advantage. Guerrillas would infiltrate, strike US and ARVN military targets, and then retreat back across the imaginary line to safety. The barrier was intended to deny the North Vietnamese the ability to infiltrate and to deny the South Vietnamese Viet Cong the ability to retreat to safe havens.

The barrier initially consisted of an integrated assembly of barbed wire, mines, defoliated areas and troop emplacements to counter-attack against penetrations and

probes by the enemy. The DCPG recognized that barrier operations would evolve within the realm of a "thinking and acting enemy" where for every action their is a reaction and a counter-action.[19] As such, they envisioned the barrier becoming a "dynamic battle of the barrier." [20]

To defeat the enemy with a barrier the DCPG planned much more than the original concept of a jungle "Maginot Line."[21] Instead, they envisioned a barrier upholstered with advanced sensors to provide constant intelligence on the enemy. *Newsweek* claimed that this "system would employ a network of noise, heat and optic detectors-and perhaps even laser-rays." [22] Added to the sensors would be patrol planes, which could retransmit the sensor data and aircraft to conduct air strikes. Other technological innovations would also be added as the battle of the barrier evolved.

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[19] Luttwak, E. (1987). Strategy: The Logic of War and Peace. Cambridge, Harvard University.

[20] Senator Gravel, (1971-72). The Pentagon Papers: The Defense Department History of United States Decision Making on Vietnam. Boston, Beacon Press. p. 120.

[21] French line of fortifications conceived in the 1930s by the French war minister Andre Maginot. It extended 200 miles along the northeastern border of France to protect against a frontal assault. It was quickly flanked and defeated in WWII by the German Army.

[22] An Electronic Picket Line at the DMZ. (1967, April 17). Newsweek, p.25.

The endstate of the barrier was a modern day *great wall of Vietnam* that would put an end to North Vietnamese infiltration. Other backers of the plan, such as Senator Mike Mansfield of Montana, even went so far as to propose that "the construction of the barrier would permit the United States to stop bombing North Vietnam." [23] Supporters of the barrier envisioned a point where technology would even replace the need for soldiers, leading to a reduction in casualties. This was referred to by some as a transition to "Blipkrieg,"[24] where the "blip" of a sensor would direct fires onto the enemy without the need for interaction with a human operator. Given the high rate of casualties incurred during the war this aspect was especially appealing to Secretary McNamara. McNamara had "previously discarded an Army proposal for a picket-line force below the demilitarized zone because it would have required an additional 250,000 men in Vietnam." [25]

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[23] Baldwin, H. (1967, July 21). US Adding 12 Miles to Vietnam Barrier Strip. New York Times, p. 2.

[24] Blipkrieg is a modification of the name Blitzkrieg which was an innovative strategy and tactic of mechanized and armored warfare developed by the Germans prior to WWII. Blipkrieg, it was proposed would have the same success but would be enabled by the blips or sensor hits produced by unattended ground sensors.

[25] An Electronic Picket Line at the DMZ. (1967, April 17), Newsweek, p. 25.

A significant source of debate for the McNamara line centered on its location. Should the line separate just North and South Vietnam? Should it extend into Laos and Cambodia? What about issues of territorial sovereignty? The original line began in the demilitarized zone. *The New York Times* noted that "a 12 mile extension of a cleared barrier strip is being started just south of the demilitarized zone in South Vietnam...the original strip 600 yards [long] was previously authorized." [26] This strip began in front of what was known as Leatherneck Square, a network of Marine Bases. These bases were located in Conthien and Giolinh and had been the scene of numerous battles with infiltrators. The 12-mile extension would increase the barrier to a total of 23 miles. With this extension went an attempt to create a sterile battlefield for the sensors. The sensors could not differentiate between a peasant or a soldier. So in 1967 with the extension of the barrier, "approximately 11,000 peasants were moved out of the cleared area to create a free-fire area." [26]

Another problem with the barrier was that the actual DMZ was approximately 40 miles long. Even erecting a barrier along all 40 miles would not eliminate the ability of the enemy to circumvent the barrier by traveling through the

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[26] Ibid, p. 2.

porous borders of Laos and Cambodia. In order for the barrier to succeed, it had to stretch across all of Laos or be erected along the entire western border of South Vietnam between both Laos and Cambodia. As the proponents of the barrier sought a solution, the government of Laos intervened. "The government of Prince Souvanna Phouma declared...that it was opposed to the construction of an electronic barrier across the Ho Chi Minh Trail in southern Laos."[27] While this signaled the end of the physical construction of a barrier in Laos, it also marked a transition toward an automated battlefield. *The New York Times* noted that, "The premier said nothing to indicate that he would consider the dropping of such devices a violation of his countries integrity." [28] While the physical construction of the barrier stopped, the DCPG began preparing for the advent of an "empty battlefield" where sensors coupled with air strikes would replace the need for ground troops.

In the end, the McNamara Line failed to achieve its purpose despite announcements by McNamara prior to his resignation "that the project would be completed late in

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[27] Lelyveld, J. (1968, January 25). Electronic Line Opposed by Laos. New York Times, p. 1.

[28] Ibid, p. 1.

1967 or early in 1968." [29] Construction slowed and then stopped. In fact, it is widely believed that with McNamara's departure, the barrier plan was allowed to die on the vine. However, the DCPG and their sensors did not die with the barrier. Instead, a new crisis occurring at Khe Sanh ensured their success and survival until late into the war. [30]

2. Khe Sanh

The success of sensors at Khe Sanh was important to the DCPG because it proved that sensors could be successful when used in a battle without front lines or linear defenses. One of the main detractors of the McNamara line had been that he was trying to employ a linear approach to a 360-degree war.

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[29] Roberts, G. (1968, March 25). Work on McNamara Line in Vietnam Near Stand Still. New York Times, p. 1.

[30] While the McNamara Line was discontinued in Vietnam, another line was completed in the Republic of Korea. Infiltrators from North Korea conducted small-scale attacks across the Korean Demilitarized Zone at the same time that the NVA were infiltrating into Vietnam. In response, the technical advances and personnel of the DCPG were also offered to the US military in Korea. This culminated in the creation of a barrier similar in makeup to that of the McNamara Line. While some publications make isolated references to this, little information is available. The use of sensors in the DMZ is ongoing and considered in many respects to be classified. Another interesting aspect is the transfer of sensor technology to the US Border Patrol. In the late 1970s, these same sensors would be used along the Texas-Mexico border to detect illegal immigrants. More advanced sensors than those developed by the DCPG continue to be used today. See Andelman, D. (1973, July 14). US Implanting an Electronic Fence to Shut Mexican Border to Smuggling. New York Times. p. 1. Also, see Bolger, D. (1991). Scenes From an Unfinished War: Low-Intensity Conflict in Korea, 1966-1968. Washington D.C., GPO.

Khe Sanh was a Marine base in the northwest corner of Vietnam. Intelligence information indicated that the North Vietnamese were conducting a massive buildup in preparation for an attack. The Marines at Khe Sanh quickly became the priority of the military and policy makers alike. In preparation for the battle to come, General Westmoreland created *Niagara I*. This was the name given to a massive intelligence preparation of the battlefield around Khe Sanh. The 7th Air Force provided many of its photo interpreters and many were flown in from the United States to analyze air and space surveillance photos of Khe Sanh. A *Niagara* intelligence center was created at Tan Son Nhut. "Impressive as the work of this center was-its photo specialists, for example, handled twice the weekly amount of film usually processed by the Seventh Air Force-it could not provide the up-to-the-minute data needed by American Commanders."[31] As a result, General Westmoreland offered the commander of Khe Sanh the technological advances and services of the DCPG.

On January 18, 1968, a team from the DCPG demonstrated the sensors for the Marines at Khe Sanh. The sensors were quickly accepted and within 48 hours air delivered sensors were being dropped by the 7th Air Force around the perimeter. The DCPG had initially planned to land ground

[31] Nalty, B. (1986). Air Power and the Fight for Khe Sanh. Washington, D.C., GPO. P. 90

teams by helicopter and implant sensors but enemy activity prevented this. Because these sensors were some of the earliest developed there was great difficulty in determining the exact location of the sensors. The sensors became used as detection of activity in an area as opposed to a pinpoint detection device. The sensors were both acoustic and seismic. Acoustic sensors could listen in on activities while their seismic counterparts would report the movement of soldiers and equipment. The following day Khe Sanh was attacked and surrounded, blinding the Marines to the enemy's activities while preventing reinforcements and support.

The initial efforts by the North Vietnamese were standoff attacks using mortars and artillery. However, on 5 February dismounted attacks began. This is the point where sensors proved their value.

The sensors provided the Marines with forewarning of the enemy attacks as they began to mass and conduct movement toward the base. Colonel David Lownds, the commander of the 26th Marine Regiment stated:

> The sensors which had been emplaced on Route 9 to the Laotian border suddenly came to life and it became obvious that a large column was moving adjacent to Route 9 toward the base... By computing the length of the column by information produced by the sensors, it became obvious to me that an enemy regiment was trying to close the base. This information coupled with possible assembly areas, allowed us to bring down upon this unit devastating firepower to breakup the impending attack.[32]

[32] Dickson, P. (1976). The Electronic Battlefield. London, Indiana University Press. p. 74.

The success of the sensors was further attested to by the regiment's intelligence officer Major Jerry E. Hudson. Major Hudson stated that prior to the advent of sensors, it was common to conduct harassment and interdiction fires using artillery and air strikes against the surrounding terrain. This was done based on a map inspection and suspected areas of enemy activity. However, once "the marines learned how to put sensor information to work, the words harassment and interdiction were stricken from the 3d Marine Division vocabulary." [33]

Another interesting lesson of the use of sensors at Khe Sanh was that just as they helped destroy the enemy they also helped reduce American casualties. Colonel Lownds went on to testify before the Senate that without the use of the sensors "his casualties would have almost doubled." [34] As knowledge of the sensors proliferated, the DCPG was deluged by requests from commanders in the field for more sensors. The DCPG supported them but rapidly began to develop a more robust plan for dealing with the enemy known by the code name Igloo White.

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[33] Nalty, B. (1986). Air Power and the Fight for Khe Sanh. Washington D.C., GPO. p. 95.

[34] Ibid, p. 75

3. Igloo White

The purpose of operation *Igloo White* was to interdict the infiltration of supplies and personnel occurring in Laos along the Ho Chi Minh Trail. *Igloo White* was designed to accomplish electronically what had been previously planned for with the McNamara Line. While the barrier required physical construction and troops on the ground, *Igloo White* had its own Air Force, and depended upon thousands of sensors on the ground. Coupled with the sensors and aircraft was the largest building in Thailand. This building was known as the Infiltration Surveillance Center. The operation lasted from late 1969 to the end of 1972 and was considered one of the most secretive, expensive and successful operations of the Vietnam War.

The method of the operation was to air deliver sensors from high-speed aircraft traveling at fast as 600 mph. The sensors were dropped in strings along trails, roads and suspected routes of enemy infiltration. A string was the word used to describe the sequential emplacement by air of sensors in a line. As a vehicle or group of soldiers would pass by the sensors, they would sequentially report "hits," which would show the location and rate of movement of the enemy as well as differentiate between vehicles and personnel. The sensors were designed to be covert. They were made to look like plants and would hit the ground like a

lawn dart burying themselves up to their antenna. Others sensors were acoustic and were delivered by parachute. "The camouflaged parachutes [would] catch in trees and hang high out of sight in the foliage." [35]

All of the sensors were autonomous. They had battery packs and transmitters in addition to their sensors. As a "hit" was registered on the sensor it would transmit the data. The data was received electronically by circling aircraft called the EC-121R, a four engine Air Force aircraft, and later by a small aircraft known as a Pave Eagle which could also be flown by remote as an unmanned aerial vehicle. Added to these aircraft were F-4s, B-52s, B-57s, AC-130 Pave Spectre and a variety of helicopters, all of which were used to conduct air strikes against targets identified by the sensors.

The last component of the *Igloo White* System was the Infiltration Surveillance Center. It had "a 20,000-square-foot operations center, a 5,600-square foot communications building, and a building for housing six 200-kilowatt diesel generating sets." [36] This building and its associated compound would be continually expanded throughout the war. It was "a windowless air-conditioned complex tucked away in

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[35] Weiss, G. (1971, March 1). SEA Sensor Fields: More Eyes and Ears. Armed Forces Journal. p. 38.

[36] Staaveren, J. (1993). Interdiction in Southern Laos: 1960-1968. Washington D.C., GPO. p

a jungle clearing and off limits to everyone but the analysts who worked there." [37] The air-conditioning was not so much for the personnel as it was for the computers that it housed. Within the building was an "IBM 360/40 [supercomputer which was] replaced late in 1968 with the faster IBM 360/65." [38] The data collected by aircraft from the sensors was retransmitted to the supercomputers in the ISC and then digested and analyzed, only then was it presented to a targeting board which would direct air strikes against the enemy. One proponent of the sensors stated that, "in response to picking up signals relayed from the trail, an I.B.M. 360-65 computer at the Air Force's Infiltration Surveillance Center in Thailand fixes targets and sends forth print-outs as impersonally as next month's bills." [39]

The building with its associated base "of about 4,700 Americans was selected for such operations mainly because of its location. Nakhom Thanom, at the northeast corner of Thailand, overlooks the jungles of Laos across the Mekong

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[37] Berry, F. Jr. (1988). The Illustrated History of Gadget Warfare: The Vietnam War. New York, Bantam Books, p. 69

[38] Ibid, p. 72.

[39] Mitgang, H. (1971, December 20). Sensors Don't Bleed. New York Times, p. 35.

River, and is only 64 miles from North Vietnam." [40] The close proximity of the ISC to the action put it in range of the aircraft which acted as the sensor relay. In addition to the ISC, "a ground relay [station operated] from the top of Nui Ba Den"[41] further increasing the communications range of the ISC. Of the Americans at the base, 400 were required to operate the computers, data processing and signal center operations, which received the sensor data into the computers. The other personnel were primarily military personnel to plan missions as well as aircrews.

The intended endstate of operation *Igloo White* was a transition from an earlier type of warfare involving the big and the few toward an era of the small and the many. The small and many would be the thousands of cheap and small unattended ground sensors that would target the enemy. The sensors would form an electronic fence along the 3,500 miles of the Ho Chi Minh Trail. This fence of sensors combined with airstrikes would provide a near real-time picture of the battlefield while targeting and destroying the infiltration of the North Vietnamese.

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[40] Browne, M. (1972, October 23). Sensors Attune US Base in Thailand to Movements on Ho Chi Minh Trail. New York Times, p. 32.

[41] Bergen, J. (1986). Military Communications: A Test for Technology. Washington D.C., GPO. P. 392.

The response time between target detection and the delivery of area weapons against the target was between two to five minutes. Much of the actual delivery of ordinance onto the target was automated. The pilots of the strike aircraft did not see their targets or pull a trigger to release their bombs. Instead, the aircraft would fly over the sensor target and release its payload at a time directed by the aircraft's computer, which operated off of sensor data. While bomb release was automated there was much more to the process. Within South Vietnam, pilots were not required to visually acquire targets. During the battle for Khe Sanh discussed earlier, automated delivery of ordinance was a standard procedure. However, in Laos the rules of engagement were very different.

In Laos, a Forward Air Controller (FAC) was required to visually acquire the target after being vectored to the target area by sensor information. The FAC would confirm the target, mark it with smoke producing rockets and then direct fighter-bombers against the target. Air strikes were forbidden against villages or against targets that were farther than approximately 220 yards away from a main road or trail. The exception to this rule was if the Laotian government or military had authorized the target. These ROE introduced inefficiency into the system in an attempt to retain the support of the Laotian government as well as to

reduce the chances that the civilian population might be accidentally targeted. This resulted in numerous sensor activations that were not acted upon because the target could not be confirmed due to weather, or the target was outside of accepted boundaries.

The tactics of an operation involved the airdrop of sensors in a string of five or six along a road, route or trail. As a vehicle passed the sensors, a pattern of activation would develop as each sensor reported enemy activity. This would enable the direction, location and speed of the truck convoy to be determined by following the activity of the enemy as it activated each sensor down the line. The arrival time of the truck convoy at the last sensor in the line would then be estimated as "point X and the coordinates of that point passed to F-4 fighter-bombers."[42] The delivery of ordinance by the aircraft would be timed by the F-4 computers to coincide with the expected time of arrival of the trucks at X which was an area as opposed to a pin point location. This was termed the strike zone. The strike zone was necessary because the sensors were "listening-not viewing devices" and could not accurately determine the exact location of each truck. The sensors

[42] Dickson, P. (1976). The Electronic Battlefield. London, Indiana University Press. p. 86.

provided the area of the activity that would be targeted by area weapons.

Igloo White was focused on the destruction of trucks not personnel. Its results were significant. In fact, the infamous Vietnam "body count" was replaced with the "truck count." The results were "12,000 trucks in 1971, its last full year of operation; 12,000 for 1970; 6,000 in 1969; and 5,500 in 1968; its first full year of operation. In all over 35,000 trucks[were destroyed], each of which carried [an estimated] 10,000 pounds of war supplies intended for South Vietnam."[43]

Despite this success there were problems. The most significant were categorized as poor bomb damage assessment and enemy forces that passed through the electronic fence without detection. Other problems dealt with the unintended consequences that were emerging as part of the automated battlefield.

The premier problem was defining whether a sensor activation coupled with an airstrike had hit a truck convoy and if hit what that had achieved. It was widely believed that the Air Force had over-estimated the number of vehicles destroyed by its operations. This came to a head one year when the numbers of trucks reported as killed exceeded the number that the US Embassy believed existed in all of North

[43] Ibid, p. 90.

Vietnam. Many of the problems were traced back to the measures of effectiveness used by the Air Force. If a shell hit within ten feet of a truck, it was designated as damaged and a hit of any kind was recorded as a kill. This led military experts to estimate that as little as 10% of the NV supplies were making it through the Ho Chi Minh Trail. The result was that most military officials began to apply a discount factor to the data. A fact finding mission led by members of the US Senate found that "[t]hese figures are not taken seriously by most US officials, even Air Force officers, who generally apply something on the order of a 30% discount factor."[44]

The most significant issue that contributed to the demise of *Igloo White*, was the use of armor and artillery by the North Vietnamese in parts of South Vietnam. In 1972, the North Vietnamese conducted a major offensive using a combined arms approach reaching as far south as the An Loc region of Saigon. How could this happen if the sensors were so successful in locating and destroying infiltration along the Ho Chi Minh trail? A number of explanations are possible. First, the munitions used by the Air Force were primarily anti-personnel. The primary type of ordinance used was the Sadeye/BLU-26B. The Sadeye was an area weapon. It

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[44] Senate Committee on Foreign Relations Subcommittee on United States Security and Commitments Abroad. (1971). Laos: April, 1971. Washington D.C. GPO.

was a cluster bomb munition designed to kill personnel and destroy thin-skinned vehicles such as trucks. It was never designed to destroy heavy artillery or tanks. Use of this munition might have damaged tanks or artillery with a direct hit but would not take them out of operation.

Second, some commanders complained that the sensors provided "them with more targets at a time when they already had enough targets, which had been discovered without sensors." This was combined with information overload caused by numerous sensor *blips,* which did not discriminate between priority targets such as tanks, and lesser priority trucks. Third was the idea of "spoofing." Spoofing was the notion that the North Vietnamese would innovate or "fool" the sensors. One officer commented before a Senate committee that "he assumed the North Vietnamese were smart enough to set off decoy explosives during attacks so that (the enemy tanks and artillery) would be counted as dead or damaged even if not hurt at all." [45]

Finally, many of the targets identified by the sensors were not acted upon because of the Rules of Engagement. In Laos, the Ho Chi Minh Trail was often obscured by heavy and persistent fog. The requirement for Forward Air Control

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[45] Dickson, P. (1976). The Electronic Battlefield. London, Indiana University Press. p. 93.

aircraft to visually confirm a target was often impossible. This allowed the enemy to infiltrate without being attacked. All of this led military planners and the United States Congress to ask whether the project was cost effective. The operation was costing the government approximately 1 billion dollars per year. Did the costs outweigh the benefits? While congress wrestled with this issue Igloo White was shut down. This was not just a response to the problems of the project but a reflection of the war effort as a whole. The war was approaching a point where the military and civilian leadership was preparing a plan for a withdrawal from Vietnam and costs of the war were being reduced.

D. TECHNOLOGY

The Jason report presented to McNamara contained a detailed discussion of the type, quantity, cost and capabilities of the proposed sensors. The initial type of sensor envisioned by the Jasons were "acoustic detectors, based on improvements of the Acoustic Sono-buoys currently under test by the Navy."[46] The plan was to take off-the-shelf hardware and modify it to serve the needs of the barrier plan. The sensors would be employed in both the anti-vehicle barrier and the anti-personnel barrier. Within

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[46] Senator Gravel. (1971-72). The Pentagon Papers: The Department of Defense History of United States Decision Making on Vietnam. Boston, Beacon Press. p. 121.

the "anti-vehicle system acoustic detectors [would be] distributed every mile or so along all truckable roads in the interdicted area, monitored 24 hours a day by patrol aircraft."[47] The quantity of sensors required to emplace a sensor per mile along the barrier amounted to "1600 acoustic sensors per month (assuming presently employed batteries with a 2-week life)."[48]

Within the anti-personnel barrier, sensors would also be used but they would be distributed more densely. The sensors to be used were also acoustic, which would make detection of foot traffic difficult. A recommendation was made within the report for the introduction of button bomblets. "Button bomblets were miniature mines developed by the Picatinny arsenal that were designed to make noise when stepped on and cue an acoustic sensor to the presence of personnel."[49] When an infiltrator stepped on the bomblet, the acoustic sensor would hear the noise from a distance as far away as two hundred feet. The problem immediately recognized was the high cost of the mines necessary to thwart pedestrian traffic. The Jasons estimated that the barrier would require 25 million button bomblets per month.

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47 Ibid, p 121

48 Ibid, p. 122.

49 Senator Gravel. The Pentagon Papers: The Department of Defense History of United States Decision Making on Vietnam. Boston, Beacon Press. p. 121.

While acoustic sensors were planned, a better sensor would be needed to eliminate the need for bomblets and the aircraft required to dispense them.

After approval of the plan and the formulation of the Jasons as the Defense Communications Planning Group, the sensor plan became problematic. The DCPG tested the employment of modified Sono-buoys, and found that the off-the-shelf plan would not work. "The equipment was not suitable for the combination of air-delivered, ground emplaced, and long-range transmission" that the plan required.[50] These limitations necessitated the rapid development of new sensors based on new criteria. Within fifteen months of the activation of the DCPG they developed and fielded acoustic, seismic, magnetic, and infrared sensors to detect the enemy besides those originally planned. The criteria used in their development ranged from the types of emanations they detected to their cost.

1. Sensors

Common to the construction of all sensors were the four basic elements of "a detecting unit, electronic logic circuit, radio transmitter, and a battery"[51] However, not all sensors were alike. The DCPG developed acoustic,

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[50] Dickson, P. (1976). The Electronic Battlefield. London, Indiana University Press. p. 35.

[51] Ibid. p. 39.

seismic, electromagnetic and infrared sensors to suit a variety of requirements and capabilities. While there were as many different types or combinations of sensors tried during the war, the following contains a sampling of the most common types.

a) ACOUBOY

The first sensors used by the DCPG were acoustic. Acoustic sensors used microphones to "listen in" on activities within range of the sensor. These were essentially modified Navy Acou-buoys previously used for anti-submarine warfare. The sonar device was removed and replaced with a microphone called COMMIKE. These sensors came in two versions, the Mark-I and Mark-II. The Hazeltine Corporation of Little Neck, New York built the Mark-1. Magnavox of Urbana, Illinois built the Mark II. The earliest Acoubuoy sensors had three detection modes. The C-mode detected vehicles, an I-mode could detect the detonation of button bomblets and a B-mode could detect both. The I-mode could detect "personnel up to 438 yards and the C-mode acoubuoy could detect vehicles at distances up to 1,094 yards."[52]

The range at which the Acouboy could report a detection was determined by the strength of the sensor power

[52] Staaveren, J. (1993). Interdiction in Southern Laos: 1960-1968. Washington D.C., GPO. p.267

source (battery) and the frequency assigned to the sensor. On average, the sensor transmission could travel up to 30 miles depending on terrain. The sensors operated on frequency channels ranging from 162.5 megahertz (MHZ) to 173.5 MHZ on a very high frequency band. Each type of sensor had thirty-one channels. Each channel was separated by 375-MHZ between channels. Within each channel were 27 identification codes that could be set before sensor emplacement. This allowed 837 individual sensors to be deployed at one time in a single operational zone without duplication. As development of the sensors progressed a different number of channels were given to each sensor to prevent duplication. The Acoubuoys were then allocated 11 channels, and the ADSIDs 12.[53]

The Acoubuoy, was parachute delivered and would catch in the high jungle foliage with its acoustic sensors hanging down. The parachute was camouflaged and would typically become tangled high in the trees where it would hang well out of the line of sight of passers by. In one incident, the Infiltration Surveillance Center monitored a group of North Vietnamese soldiers that detected an acoubuoy hanging in the trees. The ISC anxious to learn the reaction of the soldiers rapidly took the tape to a Vietnamese translator. The transcript of the conversation was not of

[53] Ibid, p. 268.

how to defeat the sensor, but of a non-commissioned officer telling a private to climb the tree and get the parachute so his wife could make clothes out of it.

b) ADSID

Seismic sensors used geophones to detect the vertical vibrations in the ground made by a person or vehicle. The Air-Delivered Seismic Intrusion Detector (ADSID) was the most common sensor of this type. The Sandia Corporation produced the ADSID device. It could be dropped by aircraft traveling at speeds exceeding 500 mph. The device was dropped without a parachute and was thrown from an aircraft in a fashion similar to a lawn dart. The sensor then used "an aerodynamic brake to slow it. As it entered the ground, the device separated into two parts-the nose buried itself far into the ground, while the tail remained at the surface, exposing only a green antenna which resembled a jungle plant."[54] Major General John Dean, a subsequent director of the DCPG commented that "in our test area in Panama I failed to see the antenna until it was pointed out to me." [55] Like most of the sensors, the ADSID

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[54] Dickson, P. (1976). The Electronic Battlefield. London, Indiana University Press. p. 84.

[55] Weiss, G. (1971, March 1). SEA Sensor Fields: More Eyes and Ears. Armed Forces Journal. p. 38.

could be emplaced by hand if desired. This would improve the accuracy of emplacement but generally was not practicable. Given the weight of an ADSID of approximately 25 pounds each, the number required and enemy control over the areas, this was rarely done.

The ADSID was unique in a number of ways. First, it was reported to be the most durable of all the sensors and contained a self-destruct mechanism that would destroy the internal components of the device if opened. This was designed to prevent an enemy from gaining access to the technology or spoofing the sensor. The "ADSID could also be instructed by remote control to pick up either men or vehicles."[56] However, the ADSID had a much shorter range than the Acouboy. It could detect personnel within 33 yards and vehicles at 109 yards.

One significant factor, which affected the use of sensors, was their batteries. The sensors employed by the electronic fence started at over $2,000 a piece. The initial batteries used were a NiCad type that lasted approximately two weeks. Since the sensors were a one shot item and 1600 were deployed per month, the introduction of a longer life battery was needed. This led to the development and use of lithium batteries, which varied in life from one to two

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56 Weiss, G. (1971, March 1). SEA Sensor Fields: More Eyes and Ears. Armed Forces Journal. p. 38.

months. These innovations resulted in the unit price of sensors rapidly decreasing. "A 1967 Acoustic Directional Seismic Intrusion Detector (ADSID) cost $2,145 but that price had dropped to $975 by 1970. This drop, added to improved batteries for longer life and greater efficiency in placing them, netted a reduction in cost-per-sensor-per-day from $100 in 1967 to less than $15 three years later."[57]

c) HELOSID

The Helicopter Seismic Intrusion Device (HELOSID) was made by the Texas Instruments Company. The HELOSID was intended for delivery by helicopter. It was almost identical to the ADSID except that it was designed to be launched from a special pod attached to a CH-3 Jolly Green Giant and had a battery life of 60 days.[58]

The CH-3 and HELOSIDs were initially used in support of sensor operations at Khe Sanh. The helicopters were configured with a pod that would shoot HELOSIDs while the pilot maintained a hover over the desired location. The plan was to orbit the location after deploying a sensor to receive verification by radio from the ISC that the sensor was in operation. More often than not, the sensor did not work. It either became embedded too deeply in the ground or

[57] Ibid, p. 84.

[58] Staaveren, J. (1993). Interdiction in Southern Laos: 1960-1968. Washington D.C., GPO. p.268

was destroyed on impact. One enterprising pilot during the battle for Khe Sanh found that these same sensors would work if they were tossed out the side of the helicopter while at a hover. [59]

d) MAGID

The Magnetic Intrusion Detector (MAGID) reacted to any metal such as a rifle or a truck. "The MAGID was almost always attached to a small seismic intrusion detector called the MINISID and wired in such a way that both seismic and magnetic activation were needed to send out notice of a target."[60]

e) EMID

The Electromagnetic Intrusion Detector (EMID) is a sensor that generated a radio frequency (RF) field around itself. If the field was disturbed by an intruder, the disturbance would cause a shift upward and downward in the RF field. This shift would trigger a detection and report the intruder.

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[59] Nalty, B. (1986). Air power and the Fight for Khe Sanh. Washington D.C., GPO. p. 92.

[60] Dickson, P. (1976). The Electronic Battlefield. London, Indiana University Press. p. 40

f) PIRID

The Passive Infrared Intrusion Detector (PIRID) was the most complex of all the sensors and "was intended to sense fine temperature changes in its field of view allowing it to count the warm bodies passing by."[61] While it functioned fine in testing it was a dismal failure in the field. One reason for the failure was a tendency to attract insects that caused it to malfunction.

g) TURDSID

Perhaps the most covert of all sensors was the TURDSID, which as its name suggested was designed to look like the excrement of a dog. It was a small contact sensor about the size of a finger that would cue a larger sensor nearby. However, when the DCPG learned that there were no dogs running wild along the Ho Chi Minh trail, it was reconfigured to look like a small piece of wood.

h) MINISID

The Mini-Seismic Intrusion Detector (MINISID), was made by RCA Corporation. It was one of three sensors specifically designed to be carried and emplaced by hand. The other sensors were the MICROSID which was smaller and even smaller still was the PSID. The MINISID was developed to count personnel and provide their location. It's value

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[61] Ibid, p. 40.

was double that of many sensors because it could operate as a stand-alone sensor or be combined with different sensors to add a seismic detection capability.

i) MICROSID

The MICRO Seismic Intrusion Detector was made by Texas Instruments. It was a recoverable sensor, typically placed along a road or trail. Each MICROSID had its own identifying code so that activity could be pinpointed in relation to each sensor. The MICROSID was designed to detect seismic disturbances to determine the number of dismounted troops that passed it as well as their direction of movement.

j) PSID

The Patrol Seismic Intrusion Detector (PSID) was very popular because it was designed for the average infantry unit. The PSID was small enough that it could be carried in an ammo pouch on a soldier's combat harness. Each PSID consisted of a 5-unit set. These could be emplaced by hand by a small patrol for ambush operations or perimeter security and later recovered. It had a small plug that was part of a larger sensor. The plug (geophone) would be forced into the ground and upon detecting footsteps would transmit a series of beeps. It had a detection range of approximately 500 meters. These small "soldier sensors"

averaged between $280 to $320 and were the cheapest of all the sensors. It was produced by Dorsett Electronics of Tulsa Oklahoma.

2. Combined Sensors

The last category was combined sensors. The combination of multiple sensors was made for two reasons. First, it enhanced the capabilities of the individual sensor to detect multiple types of targets in different ways. Second, the combination of sensors was an attempt to limit the number of false detections. By requiring the sensor to detect the same target in multiple ways before transmitting a "hit," the chances of a false report were reduced. MINISIDS were used in this way and were usually attached to a MAGID. The combination required a both a magnetic and seismic detection before reporting. Yet, another was the ACOUSID, Acoustic-Seismic Intrusion Detector.

3. False Activations

Sensitivity of the sensors to activity other than infiltration was a major problem for the DCPG. The initial tests of the sensors were conducted in Panama with the intent of replicating the conditions to be found in Vietnam and Laos. The anti-vehicle sensors performed well during the initial tests in Panama but the environment in Laos proved much different. The presence of frogs, animals and thunder caused a sensor activation rate three to four times higher

than in Panama. This led to "491,814 ADSID activations and 125,649 acoustic acoubuoy activations" during the initial deployment of sensors. [62] As the analysts at the ISC became more experienced in the use of these sensors, they rapidly learned to differentiate between the enemy vehicles and the environment. An aid in this was the employment of combined sensors, which required the detection of multiple types of emissions before reporting.

E. ANALYSIS

In Vietnam, sensors were designed not to provide a capability but to fill a requirement. Sensors became a substitute for ground troops. Information from the sensors provided a precise location and description of the enemy over hundreds of square miles. This timely, and accurate information enabled small, mobile reaction forces to respond to the site of a detection. The performance of sensors demonstrates how a small military force such as the air force in Laos or the Marines at Khe Sanh when equipped with information from sensors can have a positive and disproportionate effect on the battlefield. However, the use of sensors in Vietnam did not achieve the success necessary to justify its cost. This was largely because the proponents of the sensors overestimated the pace at which technology

[62] Ibid, p. 282.

would develop enabling greater performance at a cheaper cost. As a result, Vietnam serves as a treasure trove of lessons about tactics, sensors and precision engagement. These lessons are relevant today as the US military prepares a force that depends on the ability to gain information superiority and precision engagement to achieve success.

As previously noted Precision Engagement has five component parts: Targeting, Command and Control (C2), the ability to achieve a desired effect, the ability to assess the level of effectiveness achieved (BDA) and the ability to re-engage when required. In order to achieve these requirements, the unattended ground sensors had to fulfill a number of criteria. (See Figure 2.1)

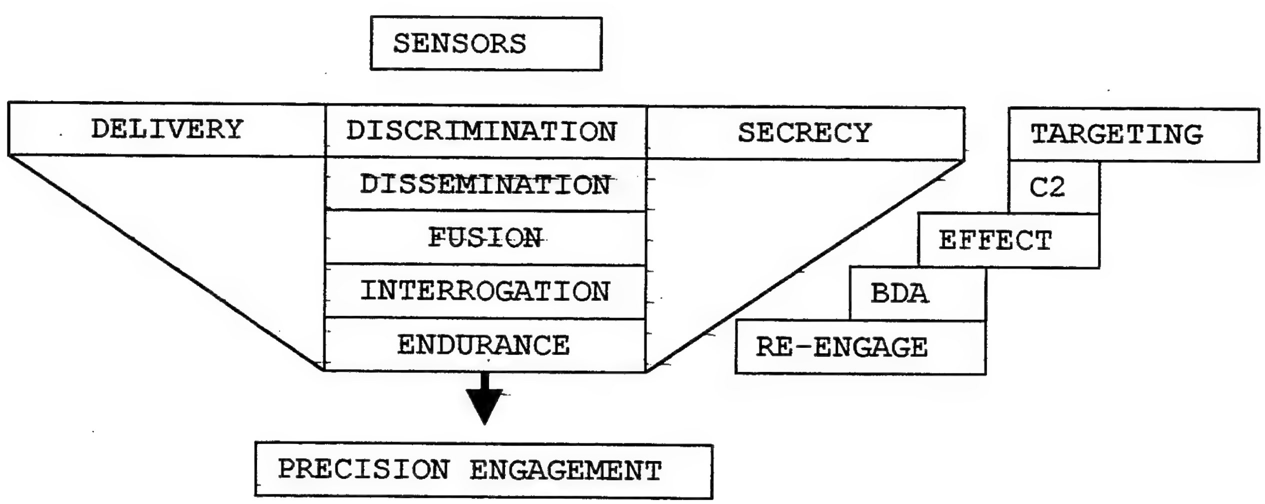

Figure 2.1 Sensor Criteria for Precision Engagement

1. **Targeting**

For targeting, ground sensors had to be delivered

to a location where they could sense the target. Second, the sensors had to be covert to prevent the enemy from destroying them or innovating around them. Third, the sensors had to be capable of discriminating between a variety of targets.

a) Delivery

The initial aircraft used for air delivery of the sensors was the OP-2E aircraft. This was a Navy aircraft produced by Lockheed. It was conventionally powered and later retrofitted with auxiliary jets. The Jasons planned to use sixty-two of these aircraft for sowing sensors in order to ensure that 800 sensors would be operating at any one time. The OP-2E regularly operated in conjunction with a small aircraft to provide forward air control of fighter-bombers for suppression of enemy air defenses. One of the major difficulties with this delivery platform was poor accuracy. During the initial stages of *Igloo White*, the aircrews relied on a bombsight consisting of a cross, made with a grease pencil. The cross was drawn on the Plexiglas of the bow and sensors were dropped using a form of *Kentucky windage*. The accuracy of this method resulted in sensors landing as far away as 900 yards from their intended target. The air force eventually acquired a number of Norden Bombsights, which greatly increased their accuracy.

Helicopters were also used for sensor delivery. The Air Force used the Sikorsky CH-3 helicopter to deliver sensors. The CH-3s were not just intended for air delivery of sensors. The CH-3s were also used for the transport of US Army Special Forces teams on sensor operations. The teams were called *Prairie Fire Spike* Teams. Each team consisted of seven to nine men, three Americans, the rest South Vietnamese. These teams implanted sensors, conducted battle damage assessment of B-52 air strikes and pinpointed critical targets.[63]

The final platform used for delivery of sensors was the F-4 Phantom. Although initially conceived as a fighter-bomber, it later became the aircraft of choice for sensor delivery. The Phantom was equipped with an SUU-42 pod that could be mounted underneath its wings. The pod contained 16 seismic sensors that could be deployed in a string formation. The F-4 was successful not only because it could deliver sensors, but because it could survive enemy anti-aircraft fire. The F-4 could fly low and fast over the sensor target during delivery without great vulnerability to enemy flak.

In addition to the method of delivery, the location that sensors were delivered to was also important.

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[63] Staaveren, J. (1993). Interdiction in Southern Laos: 1960-1968. Washington D.C., GPO. p: 270 and 283.

In Laos, the Laotian Government was willing to allow an *electronic fence* instead of actual troops on the ground. In effect, it did not view a technological substitute as a violation of its sovereign territory. Although bombing was conducted in conjunction with the sensors, it appears that the Laotian Government viewed the sensors much the same way that others view surveillance aircraft. While American U-2 spy planes were shot down over China and the USSR during the 1950s and 1960s, their use did not precipitate a war.[64] One of the values of sensors may be the perception that they do not represent a hostile intent.

b) Secrecy

All of the sensors were designed to be covert. Most were painted to blend in with their surroundings and were made as small as was cost effective to minimize their visual signature. In other cases, the imagination of the DCPG led them to design sensors that would replicate their surroundings. Some sensors were even equipped with self-destruct devices that would destroy the mechanical workings of the sensor if opened. This was an attempt to deny the enemy access to sensor technology. It was also an attempt to prevent the enemy from devising counter-measures for

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[64] Schelling, T. (1995). The Role of Nuclear Weapons. In Derington, L., Mazarr, M. (Eds.) (1995). Turning Point: The Gulf War and US Military Strategy. Boulder, Westview Press.

innovating around the sensors. This was referred to as *spoofing.* Air Force officers assumed that if the infiltrators knew where the sensors were located that they would detonate explosives during an air attack to make the pilots think that they had hit their targets. In one known example, the DCPG developed ravioli sized mines known as *Gravel* to channel the movement of the North Vietnamese soldiers toward the sensors. The NV forces employed oxen dragging logs through critical areas defeating the *Gravel* but at great expense to the oxen.

While there are other examples available, the evidence does not indicate that the North Vietnamese were successful at defeating the sensors. Some of the evidence to support this came from the sensors themselves. Three specific cases occurred in which the acoustic sensors recorded their interactions with the North Vietnamese. In a case already mentioned, the Vietnamese wanted to get hold of the delivery parachute to make clothes out of it. In another, the Vietnamese could be heard cutting down the tree which the sensor was in. The cutting sound was followed by a loud crack and screaming. The analysts believe that when the tree was cut, it fell on the North Vietnamese. The last case was on in which the ISC could actually hear a sensor, being urinated on.

While the use of covert sensors was successful, it had an unintended consequence. The covert nature of the sensors reduced any deterrent value that they might have had. The employment of covert sensors created an *empty battlefield* where there were no soldiers, and the only evidence of the US military was a battlefield upholstered with sensors. If the North Vietnamese were looking for soldiers or tanks, and all they saw was a clear avenue of approach for infiltration, this may have actually encouraged them to continue their activities

c) Discrimination

Discrimination of targets was enabled by a variety of sensor types. These types ranged from seismic, infrared, electro-magnetic, magnetic, pressure, to acoustic. Many sensors often employed more than one type of capability. This allowed for discrimination between tanks, trucks, and personnel. A combination of sensings also reduced the possibility that a sensing was a false activation caused by the weather, terrain (underground seismic activity) or animals.

The sensors were very successful in discriminating between vehicles and humans but not between combatants and civilians. Thus they were most useful in a demilitarized zone or an area of intense fighting. The sensor technology

advanced to the point where it could identify a soldier through magnetic sensors. The magnetic sensor would detect the metal in the soldier's weapon and report the soldier as a combatant. However, the same sensor would also report "combatant" if a little girl carrying a metal pail or an old man carrying a metal shovel to his farm passed by the sensor. Likewise, a seismic detector would also report combatant if it detected the vertical motion in the earth created by a soldier, old man, or child walking by. This danger was widely recognized by the sensor operators and led to the use of *Rules of Engagement (ROE)*.

The *Rules of Engagement* were different in each area of operation. In the area around Khe Sanh where the Marines were under constant attack, any sensor activation could be engaged. In Laos, there was a mix of combatants and non-combatants. This dictated that a sensor activation could only be fired upon if the target was outside of a civilian area and only after the target had been verified visually by a forward air control aircraft or ground reconnaissance team. While many sensor activations were undoubtedly enemy formations, they were not acted upon because they did not satisfy the rules of engagement. The danger was that If a sensor was linked directly to a weapon system, without rules governing the use of force, it might

result in an atrocity that would rival My Lai.[65] This demonstrates that although the rules of engagement were inefficient in one respect, the inability of the sensor to discriminate between combatants and civilians required it.

2. Command and Control

Command and Control (C2) is the ability to manage a diverse amount of forces and resources to accomplish a particular mission. Central to successful C2 is the ability to disseminate information about the enemy.

a) Dissemination

In defensive operations at Khe Sanh, the marines were quickly trained to use a remote sensor monitor. This enabled the Marines to monitor the battlefield without significant augmentation of their intelligence center. It also provided the Marine Commander with up-to-the-minute information from the sensors for targeting without placing ground reconnaissance forces and aircraft in harms way. Sensors provided the Marine Commander the ability to visualize the battlefield using information as opposed to intelligence. While *Niagara 1's* satellite and aerial photo interpreters could not keep pace with intelligence, the sensors bridged the information gap needed to seize the

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[65] Stockholm International Peace Research Institute. (1974). World Armaments and Disarmaments: SIPRI Yearbook 1974. Cambridge, The MIT Press.

initiative. This enabled the Marine Commander to employ joint firepower to disrupt attacks and prevent casualties to his own force. As already noted, the Marine Regiment's Intelligence officer said "the words harassment and interdiction were stricken from the 3rd Marine Division's vocabulary."[66] With greater precision, the need for firing into the blind in hopes of hitting the enemy disappeared.

In the offense, sensors allowed the battlefield to be operated by remote. The Intelligence Surveillance Center could monitor the actions of the enemy from hundreds of miles away. The information was then displayed on computer screens. However, the inability of the sensors to process their own information required two supercomputers. The use of these computers resulted in a great increase in the number of personnel required to operate and maintain them. Each supercomputer had approximately four disk units, five magnetic tape units, a high-speed card read punch, and at least two teleprocessing typewriter terminals. It had a 360 processor and a 265K storage capability.

Currently, the technology exists enabling sensors to be equipped with this technology eliminating much of the need for the computers. However, even without this capability, computer technology has progressed to the point

[66] Nalty, B. (1986). Air Power and the Fight for Khe Sanh. Washington D.C., GPO. p. 95.

that one personal computer today could replace one of the IBM 360 supercomputers. In effect, the personnel required to manage the information could be reduced from 400 to a handful. Additionally, the tens-of-thousands of square feet of office space required for the ISC would not be necessary. However, it is important to note that while the ISC was necessary, it was successful in conducting the war remotely from outside of the country in which the war was taking place.

3. Effect

The ability to achieve a desired effect against a target is not restricted to the sensor itself. It encompasses accurate targeting, the size and type of force allocated to the mission and the type and quantity of munitions expended against a target. In order to facilitate these requirements, various types of sensor data must be fused together to provide a complete picture of the target and the battlefield.

a) Fusion

The use of ground sensor data was most effective when it was fused together with optical images obtained from air and space sensors. The enemy was detected using multiple types of ground sensings to determine their location, number and direction of movement. The sensings discriminated

between the types of targets detected. These detections were often compared with air and space surveillance photos to develop a complete picture of the battlefield. While the targets could be attacked based on ground sensor information alone, the combination of optical images and sensor information enabled commanders to visualize the actions of the enemy while gaining a better understanding of the enemy's intent.

The use of sensors at Khe Sanh is a case in point. The combination of an optical image combined with up-to-the-minute ground sensings enabled the Marine commander to visualize not only where the enemy was but also where the enemy intended to move. As the commander monitored the sensor activations, this information was compared with old aerial photos that showed previous NV artillery emplacements. This combination enabled the commander to determine that these emplacements were being re-occupied.

4. Bomb Damage Assessment

BDA is the ability to assess the level of effectiveness of an airstrike or attack by determining if a bomb or munition had hit its target, and if hit what effect that had achieved. Various methods have been employed to assess bomb damage. The ultimate goal is to get the target to tell you if it is alive or dead. This is done by observing its actions or signature relative to a functioning target or

previous observation of the same target. This is best described as interrogating the target.

a) Interrogation

Vietnam is a mixed lesson in the ability to interrogate a target. The US Air Force attempted to use measures of effectiveness (MOEs) to assess incremental damage against the enemy. This resulted in a loss of credibility for much of the BDA process. While sensors had progressed considerably, the technology was not available to detect the emissions of individual vehicles, detect radio transmissions or take optical images from the sensors. However, the sensors could continue to detect vehicle and personnel movement (if they were not killed) and could continue to listen in on activity in the target area. This assisted in conducting BDA but it was not a complete solution.

5. **Re-engage**

After assessing the effect of munitions against a target, the assessor will invariably conclude that some have escaped destruction or have sustained damage, which allows them to continue operating. This necessitates the ability to reengage a target when required. Central to this requirement is the endurance of a particular sensor. If it can operate 24 hours a day every day, then it can support targeting,

command and control, and BDA for a second strike against the same target.

a) *Endurance*

Ground sensors were capable of providing 24-hour coverage of the battlefield. As many as 800 sensors per month were airdropped along the Ho Chi Minh Trail. The large quantity of sensors was required due to the short life span of the batteries. The battery life of the sensors was also the most significant component driving their cost. The sensors were a single use technology. The earliest sensors had a life of approximately two weeks at a cost of $2100 each. By the end of the conflict, the life span of sensor batteries had increased to two months. This reduced the cost of the operations, enabled greater coverage of the battlefield, and reduced the number of times that aircrews and ground teams would be placed in harm's way in order to deliver the sensors.

III. SINAI

If a little knowledge is dangerous,
where is the man to have so much to be out of danger

-Thomas Henry Huxley

A. INTRODUCTION

A study of the Sinai demonstrates the value of sensors in promoting peace. While sensors in Vietnam were used by military forces for precision engagement, sensors in the Sinai were used by the US State Department for peacekeeping. Many of the same lessons learned from Vietnam are also present in the Sinai, corroborating the value and relevance of those previously learned lessons. While the Sinai did not return to open warfare, the sensors did provide precise locations of activity within the confines of the Disengagement Agreement. While the current military concept of sensors and *Precision Engagement* focuses on attacking and destroying targets, this case study demonstrates their use in *Military Operations other than War*.

B. BACKGROUND

At the end of the Yom Kippur War, the Israelis and Egyptians found themselves with military forces on both sides of the Suez Canal. The Israeli forces held a commanding position on the main road leading to Cairo. The

Egyptian Sixth Army was trapped behind these forces in the Sinai and all of their logistical lines had been cut. This hastened the desire of the Egyptians to reach an agreement in order to prevent the slow starvation of their Sixth Army. While the Israelis were in a better position to negotiate, they required a force of 100,000 men to maintain their military position in Egypt and the Sinai. These forces consisted primarily of reservists called up on short notice. The inability to return these men to their civilian jobs and the cost of supporting them caused the Israeli GNP to drop to 70% of its pre-war level. Added to this was the Israeli concern for soldiers being held as prisoners of war in Egypt. With these concerns, neither side could hold out for long.

Henry Kissinger, the US Secretary of State successfully mediated a cease-fire through "shuttle diplomacy." Kissinger had written what was considered to be a vaguely worded cease fire agreement which both sides had agreed to sign. The agreement was intentionally left vague to sidestep problems and allow incremental steps toward peace. This agreement led to negotiations at kilometer 101 on the Suez road which were designed to "fill in some of the blanks" of the Kissinger sponsored cease-fire.[67] After four days of UN supported

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[67] Associated Press. (November 26, 1973). Settlement on the Suez Road. Newsweek. p. 44.

talks, Israeli Major General Yariv and Egyptian Lieutenant General Gamazy signed the "Six Point Agreement" on November 14, 1973. The agreement formalized the cease-fire, resulted in the exchange of POWs, and authorized the use of UN peacekeepers to monitor the movement of non-military Egyptian supplies to the Sixth Army. This agreement was the first of four agreements that would pave the way to peace in the Sinai between Israel and Egypt. It is commonly referred to as the "Kilometer 101 Agreement" because of the location of the initial peace talks.[68] This marked the first time in 25 years that direct talks were conducted between Israeli and Arab officials. Afterwards, Israeli Defense Minister Moshe Dayan said "At last, we have arranged things by talking like human beings". [69]

1. The Sinai Separation of Forces Agreement

The Six Point Agreement lacked the ability to provide for long term stability and peace between Israel and Egypt. Israeli and Egyptian Forces were still located on both sides of the Suez Canal and all movements of supplies required inspection and approval by UN observers. Despite the cease-fire agreement, small-scale engagements continued to be fought west of the Canal. The Egyptian government feared

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[68] Borchgrave, A. (November 26, 1973) Kilometer 101-Inside the Tent. Newsweek. p. 47.

[69] Ibid, p. 44.

that the Israelis would continue their advance on Cairo and sought to disrupt Israeli preparations. In the two months between the cease-fire and the first disengagement agreement, 452 skirmishes occurred west of the canal.

Given the desire to achieve a buffer zone to prevent further attacks, the Israelis and Egyptians entered into the Sinai Separation of Forces Agreement on January 18, 1974. The terms of the agreement resulted in the withdrawal of the Israeli forces to the high ground of the Giddi and Mitla passes in the Sinai. The Israelis were willing to make this concession because the passes were the strategic high ground. In 1973, there were few trafficable routes through the Sinai Peninsula. There was a paved road along the northern coast but this route was considered to be vulnerable militarily. In the center were two large roads through the Giddi Pass in the north and the Mitla Pass in the south. There were a few trails but they would not support a large-scale military operation and many were channeled into either the Giddi or Mitla Passes. To the south was a barren and unpopulated territory, which was a "sea of sand" and was not passable by vehicle. These geographical constraints made the two passes the center of gravity controling all military actions in the Sinai.

With the signing of the agreement, the Israeli forces withdrew to the passes in a zone approximately 20 kilometers

east of the Suez Canal. The Egyptians in turn withdrew the Sixth Army west across the canal. A United Nations Emergency Force was created and positioned in a buffer zone approximately 10 kilometers wide and 165 kilometers long between the Israeli and Egyptian positions. On either side of the buffer zone were zones in which type and number of forces and weapons each side could garrison were limited.

2. The Sinai Interim Agreement

This agreement was part of Kissinger's, step by step approach to achieve a diplomatic solution. The Sinai Interim Agreement was the third of four and was chiefly concerned with the return of the Giddi and Mitla Passes. President Sadat wanted the Israelis to withdraw east of the passes. He feared that Israel might continue it's advance on Cairo and wanted to regain the strategic high ground in the Sinai. A second issue was the return of the Abu Rudeis and Ras Sudr oil fields that Israel had captured during the war. These resources were a significant source of income, especially to a country that had been soundly defeated in war. President Sadat wanted the negotiations for the passes and oil fields to be treated as a military disengagement as opposed to a political agreement. Sadat feared that any political agreement with the Israelis might be perceived as a softening of Egypt's position toward Israel.

The Israeli Government had other ideas. The first was to divide the Arab coalition politically to prevent fighting another war against a unified Arab front. Also at issue was the maintenance of strategic depth for early warning of another Arab attack. Prime Minister Rabin wanted Sadat to renounce the current state of belligerency in order to divide Egypt from her allies. This necessitated that any agreement have strong political overtones. Israel had suffered not only militarily at the hands of the Arabs but economically as well. Israel was still reeling from an economic boycott by the Arab coalition. The separation of Egypt from her allies might lead to an end of the embargo between Israel and Egypt.

The second idea was Israel's refusal to relinquish its electronic monitoring station at the western end of the Giddi Pass. Israel felt that this intelligence station was essential. The distance between Cairo and Tel Aviv was short and any settlement necessitated that Israel have early warning. This would enable Israel to mobilize it's military which consisted primarily of reservists. Finally, Prime Minister Rabin refused to relinquish control of the oil fields to the Egyptians. The oil fields supplied Israel with approximately 50% of her oil needs and the Arab economic blockade made this resource a national security issue. This particular issue was resolved through the assistance of the

Shah of Iran. On February 18, 1975, the Shah stated that he would be willing to sell oil to Israel in exchange for the return of the Abu Rudeis and Ras Sudr oil fields to Egypt. This left the issues of early warning and political settlements at the forefront.

President Sadat proposed that a solution might be achieved by stationing American military forces in the Sinai. This was not the first time that this had been proposed. However, Secretary of State Kissinger was opposed to the idea. The American people had recently witnessed the fall of Saigon on television and the idea of placing troops into action so soon was politically impossible. Israeli Defense Minister Peres sought to modify this proposal by suggesting that American civilians monitor the Sinai from an electronic monitoring station. As the negotiations continued, the Egyptians consented to this idea but stipulated that if Israel had a monitoring station in addition to the American presence, then Egypt must have one as well. Although Kissinger was averse to placing Americans in the Sinai as a buffer, it eventually percolated to the top as the one solution that both parties would accept.

The Sinai Interim Agreement was finally signed on September 4, 1975. The American presence took the form of US military overflights for surveillance and the monitoring of ground sensors by American civilians in the buffer zone.

The surveillance flights and the civilian monitoring were considered separate and distinct. However, both fell under the umbrella of the newly created Sinai Support Mission (SSM). The SSM was an interagency headquarters that reported to the US National Security Council on all matters related to support of the Sinai Interim Agreement. Underneath the SSM was the Sinai Field Mission (SFM). The SFM was the action arm of the Sinai Support Mission and concerned itself strictly with the emplacement of early warning sensors in the Sinai and their monitoring by American civilians.

3. Camp David Accord

In 1979, the Camp David Accord was signed between Egypt and Israel. This agreement led to a phased withdrawal of Israeli forces from the Sinai. The withdrawal started in April of 1979 and was completed by April 1982. The buffer zone remained intact, as well as the limited force zones with three zones for the Egyptians and one for the Israelis. The Israelis were also allowed to maintain four electronic monitoring stations as part of the agreement. The charter of the Sinai Field Mission was changed marking a transition to on-site inspections of areas formerly held by the Israelis and low level aerial surveillance flights by US aircraft. The sensor fields and monitoring of the Giddi and Mitla Passes officially shut down on January 25, 1980. Further monitoring of the passes was deemed unnecessary as "the

parties had developed a sufficient amount of confidence that such an elaborate system was not needed."[70]

C. TACTICS

The tactics of using sensors in the Sinai were defensive and linear and were intended to provide tactical early warning of an attack by either the Israelis or Egyptians. Sensor monitoring was tactical because once a sensor field was activated by an intruder at one end of a pass, "it would not take a vehicle more than one-half hour to transit" to the other end.[71] The purpose was to support the peace process through a civilian US presence and monitoring of the Giddi and Mitla passes. Monitoring of the passes would provide for control of a small, key geographic area that would produce a stabilizing effect over the entire region. The monitoring of sensor fields by American civilians would also provide an objective third party, which would monitor the Sinai for violations, referee disputes, and enable the partitioning of belligerents. The method was to increase the amount of timely and accurate information available to both sides. The information necessary to do

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[70] Vannoni, M. (1998). Sensors in the Sinai, 1976-1980. Sandia National Labs, New Mexico. Section 3, p. 4.

[71] Peyer, R. (April, 1978). Between Egypt and Israel: The Establishment of the US Sinai Field Mission. p. 18. Unpublished paper obtained from the C. William Kontos Collection, Gerald R. Ford library, National Archives.

this would come from activations of unattended ground sensors placed along roads and the open expanses surrounding the Giddi and Mitla Passes. If sensors detected unauthorized activity, a report would immediately be made to the Egyptians and Israelis as well as the US National Security Council. American civilians would immediately investigate any violation. The intended endstate was to prevent minor incidents or misperceptions from escalating to open conflict. This would enable both parties to build confidence and trust, enabling further peace efforts.

The organization established a small headquarters in Washington D.C. led by a representative of the President of the United States and staffed by State Department Officers. This organization was titled the Sinai Support Mission (See Figure 3.1). Underneath the SSM came its field-operating agency responsible for the construction and day to day monitoring of the sensors. This field agency was named the Sinai Field Mission (See Figure 3.2).

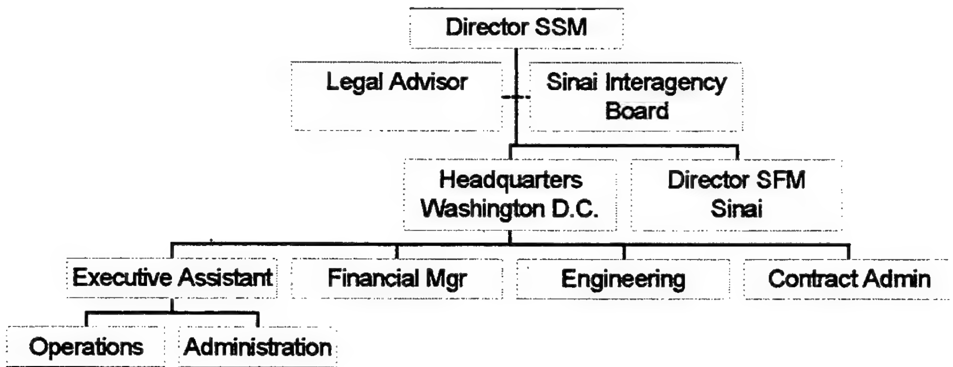
1. Sinai Support Mission

The US Sinai Support Mission (SSM) was established on January 13, 1976 under the provisions of Executive order 11896. The specifics of the Sinai Support Mission were derived from a memorandum written by Henry Kissinger. At the time, there was great concern over the mission timeline because there were less than five months between the signing

of the Sinai Interim Agreement and the time at which monitoring had to be in place. The sensors had to be in operation by February 22, 1976, the date set for the turnover of Israeli occupied lands to the United Nations force. Additional difficulties were expected because Kissinger had been opposed to using the Department of Defense (DOD) to conduct the monitoring. Since DOD was the only agency with the personnel and equipment on hand, this would be a tall order for another agency to fill.

The SSM was quickly established under National Security Decision Memorandum 313. This established the basic organization of a director and a staff of 14 personnel from the Department of State and the US Agency for International Development. The director would report to the president through the National Security Council and would have an interagency board of advisors. Mr. C. William Kontos was chosen as the Director of the SSM. Director Kontos also served as the chairman of the Interagency Management Board. On the Board were representatives of the Department of Defense and State, US Agency for International Development, the Arms Control and Disarmament Agency and the Central Intelligence Agency. This board was established under the executive order. It enabled Director Kontos to draw on a

large pool of experts to support the peace initiatives.[72] Director Kontos also had the benefit of engineering and technical support through a contract with the MITRE Corporation.



Sinai Support Mission Organization
Figure 3.1

The U.S Congress approved the establishment of the SSM and SFM. They also stipulated that while members of the Department of Defense could not participate in the mission, they could assist with the initial setup and establishment of the sensor fields due to the time constraints. Congress directed that active duty military and intelligence personnel could not participate in the mission. However, those that had retired from the military or intelligence services before October 13, 1975 could serve in the SFM. Congress also specified that the number of personnel

[72] US Congress, Senate. (April 13, 1977) United States Sinai Support Mission: Second Report to Congress. Washington D.C., GPO. p. 4. Obtained from the C. William Kontos Collection, Gerald R. Ford Library, National Archives.

assigned to the Sinai Field Mission would not exceed 200 personnel. The use of a private contractor to establish and support the mission was authorized and an intent to contract was published in the *Commerce Business Daily.*[73] Additionally, sensors used by the field mission were available from the on-hand stocks of the Department of Defense. These initial stocks were sensors that had been developed for use in Vietnam.

An interagency site survey team was sent to the Sinai on 2 December. Nicholas G.W. Thorne, a career Foreign Service Officer and retired Marine Corps officer led the team. He would later become the first director of the Sinai Field Mission. In three days, the team identified all technical and logistical requirements to include locations of the base camp, four sensor fields, and watch stations. A request was made by the Israelis to move one of the sensor fields farther west on one of the routes but this was denied on the basis of the signed agreement.

2. Sinai Field Mission

The Sinai Field Mission (SFM) was the action arm of the Sinai Support Mission. It was responsible for carrying out all aspects of the electronic monitoring. Within one month

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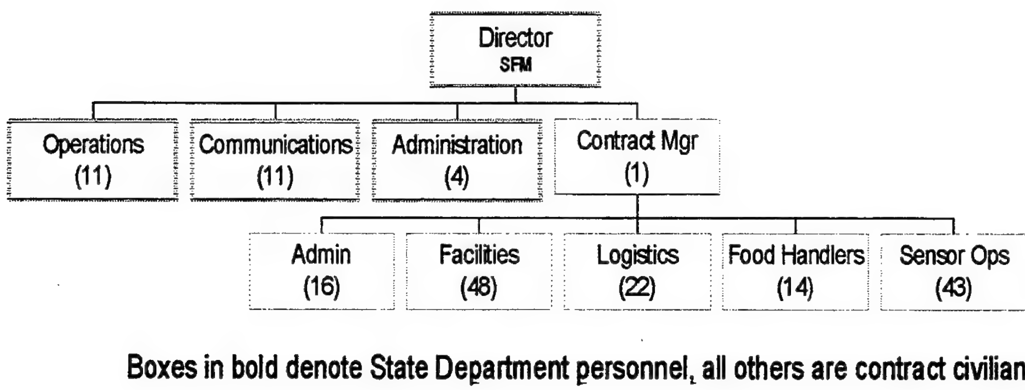
73 The text of the *Intent to Contract* can be found in Ford, G. , Kontos, C. (April 13, 1976) First Report to Congress: United States Sinai Support Mission. Obtained from the C. William Kontos Collection, Gerald R. Ford Library, National Archives.

of the published intent to contract, six companies had submitted proposals. A selection committee chose the contract proposal submitted by E-Systems Inc. E-Systems was an international electronics and aerospace firm. The contract was signed on January 16, 1976. The company would provide the personnel and equipment minus the sensors to conduct the mission. These personnel would in turn report to a small cadre of State Department Foreign Service officers who would serve as the leadership of the SFM (Figure 3.2).



Organization of Sinai Field Mission
Figure 3.2

On January 20, 1976, the first installment of equipment and personnel arrived in Tel Aviv and construction of the site began on January 23, 1976. The four sensor fields required as part of the signed agreement were installed in four days. By February 19, 1976, the SFM was fully operational. This was achieved 28 days after the start of the construction and 3 days ahead of schedule. The SFM

officially began operating on February 22 in accordance with the Sinai Interim Agreement.

While the SFM was fully operational, its facilities were temporary. This required that construction continue throughout the year. During one particular week in June 1976, 240 personnel were in the Sinai to complete construction of the base camp. The number of personnel exceeded the congressional mandate; however, this was expected and authorized to insure a timely completion of the facilities. Once the permanent facilities were completed on July 4, 1976, the number of personnel required dropped to 165 and remained relatively constant throughout the duration of the mission. While the congressional limit of 200 personnel had been established based on the monitoring requirements of the sensors, the number could have been much lower. During the initial planning stages of the SFM, the Department of Defense argued that "it was technically feasible to install the sensor fields and operate them remotely-without manning the watch stations-with substantially fewer than 200 personnel."[74] This option was not chosen because Congress believed it was essential to maintain a US presence in the buffer zone.

Other options relating to personnel were considered. One option involved the use of foreign nationals to operate

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[74] Ibid, p. 12.

the watch stations. This option was shelved due to the difficulty of conducting background checks as well as Israeli insistence on Americans in the Sinai. The Israelis expressed a lack of confidence in both foreign nationals as well as some member nations of the UN. This issue would resurface in later years after the monitoring had been in place. The US Congress solicited alternative ideas to reduce costs and the American presence in the Sinai by using foreign nationals. The Egyptian and Israeli governments opposed this idea for three reasons. First, it would take a successful system, which had a unity of command under one nation and splinter it under multiple nations. Second, there were security and administrative difficulties involved in the import of foreign nationals into the SFM. This would require negotiations with multiple nations in order to mitigate these difficulties, making the entire program much more complex. Third, employing foreign nationals would alter an element of the original agreement, which could open the door for other changes. Both the Egyptians and Israelis believed that this could cause the original agreement to unravel.[75]

[75] Carter, J., Kontos, C. (October 13, 1977). Fourth Report to Congress: The United States Sinai Support Mission. p. 11. Obtained from the C. William Kontos Collection, Gerald R. Ford library, National Archives.

Central to the success of the SFM was the principle of "symmetry." In order for the SFM to be regarded by both the Israelis and Egyptians as fair and impartial, all actions by the SFM had to be evenhanded. If the SFM contracted for workers to take rest and recreation, half would go to Israel and half to Egypt. When housing was contracted for families of State Department Foreign Service officers, half would live in either country. This principle of symmetry was carried out with respect to all possible issues ranging from logistics to notification procedures of violations. This enabled the SFM to maintain a maximum of credibility in all of its actions.

a) Base Camp

The Base Camp consisted of an eleven-acre compound that was located 3 miles north of the Giddi road. It was built on a 2,600-foot high plateau, which partially overlooked the west entrance to the Giddi pass. The nearest populated area was the city of Suez located fifty miles to the west-southwest. Cairo, Egypt was 155 miles northwest across the Suez Canal; Tel Aviv was 240 miles to the northeast. The camp was designed to be a self-contained community that would provide the full range of municipal services necessary for its personnel stationed in the Sinai. The initial base camp was temporary and relied on the use of

"Kelly closures," prefabricated steel and fiberglass panels for building construction. Within a year, the permanent base camp was constructed using prefabricated concrete modules shipped from the United States. The modules for the permanent camp were originally built for use as a Holiday Inn in Texas. The permanent base camp was capable of supporting all personnel and missions. Some temporary Kelly closures were retained for storage and administrative functions.

b) Watch Stations

Three watch stations were established in the Sinai, as called for in the original plan, with the base camp doubling as the fourth. The planned site for the base camp proved inadequate, however another was chosen out of sight of the west-end of the Giddi Pass. The speed at which the plan had to be accomplished and the limits on funding prevented a fourth station from being constructed. This meant that the sensor field at the west end of the Giddi pass had to be monitored remotely. All other sensor fields had watch stations that allowed visual oversight of the activity within the field. Each of the stations were permanent, air-conditioned facilities which were enclosed by chain link fences. Within each station, there was always a minimum of two personnel on duty. Personnel within each of

the stations had a variety of optical and night vision devices for observation of the sensor fields.

c) Sensor Fields

The Mitla and Giddi Passes run in a generally east-west direction. They are located just south of the mid-line of the buffer zone. The two-lane road that runs through the Giddi Pass is approximately 15.5 miles long. The two-lane road that runs through the Mitla Pass is 18.6 miles long. A single road that is ten miles long connects the two passes. The total area under sensor surveillance was approximately 620 square miles. This was divided among four sensor fields. Two sensor fields were allocated to each pass and within each field were a variety of different sensors. Sensors were employed in strings, which could be several thousand yards in length. Strings were placed across the passes and along the roads through the passes. Individual sensors within the strings could be positioned up to ten miles away from their associated watch station without the use of a radio relay. The relationship between the sensor fields and the watch stations they reported to were:

"Mitla West Field-Mitla West Watch Station
Mitla East Field-Mitla East Watch Station
Giddi East Field-Giddi East Watch Station
Giddi West Field-Mitla West Watch Station" [76]

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[76] Ford, G., Kontos, C. (April 30, 1976). First Report to Congress: The United States Sinai Support Mission. p. 30.

d) *Communications*

The sensor early warning system in the Sinai had three major functions: "detection of movement through the Mitla and Giddi Passes, identification of the vehicles or personnel involved in the movement, and reporting unauthorized movements." [77] Sensors accomplished the first two functions and the last function relied upon State Department personnel and their communications.

The SFM maintained extensive communications capabilities to facilitate the reporting requirements of Sinai violations as well as the conduct of day to day operations. At the outset, notification of the Egyptians and Israelis was made by voice communications from the Sinai Field Mission to the Egyptian and Israeli watch stations in the Sinai. This was later changed to streamline communications, with the SFM reporting directly to the Israeli Defense Forces in Jerusalem and the Ministry of War in Cairo. This modification was made by recommendation of all parties and the E-Systems contract was amended in the amount of $230,000 to make it possible.

Obtained from the C. William Kontos Collection, Gerald R. Ford library, National Archives

[77] Ford, G., Kontos, C. (January 11, 1977). Second Report to Congress: United States Sinai Support Mission. p. 11. Obtained from the C. William Kontos Collection, Gerald R. Ford Library, National Archives.

Teletypes were the primary method of communications used between the SFM, Israel and Egypt. This is because it provided a written record of communications and provided little opportunity for misinterpretation. These reports were prepared and signed by a Foreign Service Officer to ensure authenticity. Teletype messages were transmitted by radio and were not encrypted. A report of a violation could be sent to each party to the agreement within five minutes. An alternate system available to the SFM was a radio link to the international telephone system as well as a secure State Department communication system. The State Department communications were kept in a location separate from others. They operated off a single side band teletypewriter.

Communications between the sensors, watch stations and the base camp were different. When a sensor was activated, it would register within the adjacent watch station. The watch station personnel would then notify the base camp if the sensor activation was known or believed to be an illegal intrusion. The watch station would notify the base camp using a very high frequency (VHF) radio message that would be followed up by a teletype message. This would then be analyzed and the notification procedures for all parties would be initiated.

e) UN Troops

United Nations Emergency Forces regularly operated in the limited force zones of the Sinai. "Armed strength within the buffer zone [was] provided by 4,400 UN troops from Sweden, Ghana, Australia, Iran, Indonesia and Finland."[78] These forces provided security at the road checkpoints into and out of the buffer zones and conducted patrols throughout the zones as well. While the UNEF forces operated in the Sinai, their activities were not conducted with close coordination or approval of the SFM. Instead, they were considered separate entities and the UNEF force did not interact with the SFM other than to notify them when they would be operating in an area monitored by sensors. Part of the reason for little coordination is because the US proposal for monitoring omitted any reference to the UN or UNEF forces. The only reference to the UNEF in the document was that violations detected by the SFM would also be reported to the UNEF forces. The only exception to this rule was the Ghanaian Battalion. This unit provided local security patrols for the Sinai Field Mission. The battalion provided 27 soldiers as a guard force for the SFM base camp and other soldiers from the same battalion provided security at the three SFM watch stations.

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[78] Kolcum, E. (August 23, 1976). New Sensors Evaluated in Sinai Buffer. Aviation Week and Space Technology p. 42.

f) Surveillance Stations

Both Egypt and Israel maintained a surveillance station in the buffer zone as part of the Sinai Interim Agreement. The Egyptian station was located 7.5 miles east of the SFM base camp. The Israeli station was located five miles northwest of the base camp. Each station consisted of "an enclave of several buildings."[79] The buildings were designed to support visual and electronic surveillance and were strictly defensive in nature. No more than 250 persons could be present at either station. These personnel were authorized to carry small arms for personal protection but all offensive weapons were prohibited.

Within each enclave was a building for use by an SFM liaison officer. This officer was a State Department employee who was empowered to inspect and approve each vehicle, person or item of equipment that entered either station. The liaison officer and the director of the SFM were the only personnel authorized to enter or inspect the surveillance stations. The liaison officers conducted announced inspections and the director conducted unannounced inspections. United Nations Emergency Force personnel would escort Egyptian or Israeli convoys to their stations but

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[79] Ford, G., Kontos, C. (April 30, 1976). First Report to Congress: The United States Sinai Support Mission. p. 26. Obtained from the C. William Kontos Collection, Gerald R. Ford library, National Archives

could not enter or inspect. The liaison officers maintained various methods of communications equipment which enabled voice and data exchange with the base camp. If a violation occurred and the base camp sent a report to a surveillance station, it was actually received by the liaison officer. The officer would then hand deliver the report by hand to the commander of the surveillance station.

g) Cost

The funds for the Sinai Field Mission were drawn from Section 903 of the Middle East Special Requirements Fund of the Foreign Assistance Act. The total cost of personnel, operations, training, maintenance and construction of the Sinai Support Mission and the Sinai Field Mission was 92.7 million dollars. These funds were spent over the course of five years with the majority being for contracts with E-Systems. These contracts paid for the initial setup and constructions costs of the project as well as day to day operations. The least expensive costs were personnel wages, training, and daily operations. The budget approved by congress called for approximately 25 million dollars for the initial site construction. Approximately half of this amount was used for construction. Another 2 million dollars was spent for sensors and monitoring equipment from the Department of Defense. The remainder of

the funds were used for wages, training and that year's daily operations. Approximately 12 million dollars was allocated in the following years for salaries and operations. The amount of funds allocated were not adjusted for inflation and were maintained at a fixed rate.

D. TECHNOLOGY

The initial design for the monitoring was to use sensors from Department of Defense stocks. These sensors had been combat proven in Vietnam and were on hand for use by the SFM. While there were numerous types available, only hand-emplaced sensors were used. The technology of the sensors allowed for remote long-range monitoring. However, the need to maintain an American presence in the buffer zone reduced the benefits of the remote monitoring capabilities. A compromise with the technology was achieved by connecting the monitoring of the individual sensor fields to their adjacent watch stations. Knowledge that the sensors would be monitored by civilians who had little to no experience with sensors required that they be simple to emplace, operate and monitor. All of the sensors had these qualities. Some of the Vietnam era sensors had self destruct devices that were designed to prevent an enemy from gaining access to the technology during war. This capability was not necessary and these devices were dismantled before use in

the Sinai. Additionally, all of the sensors were unclassified and knowledge of the sensor technology could be shared with the Israelis and Egyptians. However, all parties considered knowledge of the sensors to be classified when speaking to parties outside of the agreement.

1. Sensors

A variety of sensors were used in the Sinai. The most common were seismic sensors because the sandy soil provided near ideal conditions for monitoring. Seismic sensors would often be combined with acoustic and magnetic sensors. Other types of sensors were "structural sensors." These were pressure sensitive cables, remote controlled video cameras and infrared beams. These were structural because they were mounted to tripods or buildings and were not meant to be camouflaged. Instead they were an overt method of monitoring activity in the Sinai and provided a visible deterrent to infiltrators.

a) MINISID-III

There were seven types of sensors used in the Sinai. The most commonly used sensor was the Mini Seismic Intrusion Detector MINISID-III. This sensor had initially been used in Vietnam and was an improved version of an earlier model. It was buried below the surface by hand. This sensor was powered by a battery that lasted

approximately one year. The nominal range of the seismic sensors was 300m for vehicles and 30m for people. However, the ideal soil conditions in the Sinai resulted in detections at 500M for trucks and 50M for personnel. Sensor activations were transmitted to the adjacent watch station by radio. Seismic sensors were emplaced in strings of three sensors each. This provided for redundancy and assisted in the identification of vehicles. The larger the vehicle the more sensors would activate not only near the road but farther away as well. The MINISID-III was 19 centimeters long by 19 centimeters wide and 7.6 centimeters high. It weighed 4.1 kilograms.

b) AAU

Acoustic Sensors consisted of Acoustic Add-on Units (AAU) which could be combined with the MINISID-III. The microphone of the AAU was attached to an electronic unit by a three-meter long cable. The method of operation was for the seismic sensor to cue the acoustic sensor. If the MINISID activated three times within thirty seconds, the acoustic sensor would begin sensing for fifteen seconds. This combination of sensing would assist the watch station officers in determining the source of the activation. If the source was an animal or low flying aircraft, the operator could listen in on the activity to assist in determining the

cause. The AAU could detect personnel at 30 meters and vehicles at up to 100 meters. Its dimensions were 25.2 centimeters long by 7.6 centimeters in diameter. It weighed 3.2 kilograms.

c) MAGID

The use of magnetic sensors in the Sinai was also in the form of add-on units, which would be combined with the MINISID-III. The magnetic add-on unit was called the Magnetic Intrusion Detector (MAGID). This sensor had a range of three to four meters for a person carrying a rifle and 15 to 20 meters for a truck. The MAGID had a module that contained an electronics unit and a plug to connect to the MINISID-III. The MAGID was constructed with a cable that had magnetic sensors at either end. The electronics module was attached to the midpoint of the cable. If both sensors detected emissions, it was probably a truck. If only the seismic sensor activated, vehicles could be discounted as the cause and it would be investigated as either a false activation or personnel. The magnetic sensor would transmit through the MIINISID-III transmitter much the same as the acoustic add-on unit.

d) SSCS

The Strain Sensitive Cable Sensor (SSCS) was buried across roads and trails and could extend for several

hundred meters. It was capable of detecting both personnel and vehicles. The cable was activated when compressed by an object passing over it. The SSCS was capable of discriminating between personnel and vehicles because it would transmit a signal proportional to the amount of weight that had compressed it. An electronics module was buried next to the SSCS. When activated, it would send an electronic pulse to a MINISID-III that would relay the pulse to a watch station.

e) Infrared

The Directional Infrared Intrusion Detector (DIRID) was an infrared break-beam device. The sensor would be emplaced on a small tripod in pairs at the start and end points of roads and large paths. For each pair of DIRIDs there was one transmitter and receiver. The DIRID could monitor a space three to seven meters wide. As an object passed through the space monitored by the DIRID, it would break the infrared beams in a sequential pattern alerting the watch station to an intrusion. The pattern of breakage would also provide the watch station with the direction of movement.

f) Video

Video cameras capable of low-light monitoring were mounted on platforms at the west- end of the Giddi Pass and

at the Base camp for local security. Operators at the base camp remotely controlled the cameras. Video cameras were needed at the west-end of the Giddi Pass because the Giddi sensor fields were monitored remotely and none of the watch stations had visual line of sight. The cameras were commercial cameras powered by solar cells. Each of the cameras also had a battery backup for use at night or during inclement weather. Some of the cameras were mounted alongside remote controlled spotlights to increase the quality of observation.

g) Imaging IR

This last sensor was a prototype called the Passive Confirming Scanner. It was intended for use during low-visibility conditions due to dust and fog. This system was determined to be unreliable and was removed after less than one year.

2. Treaty Violations

Over the course of monitoring the Sinai, 90 violations of the agreement occurred. These violations occurred within the area being monitored as well as the Israeli and Egyptian monitoring stations. Israel was responsible for sixty-seven of the violations. Egypt was found responsible for two of the violations. Nineteen other violations were attributed to

unidentified aircraft and two to unidentified personnel.[80] The majority of the violations involved unauthorized Israeli aircraft, which strayed to close to the buffer zone. A few of the violations involved personnel or vehicles. Egyptian violations were for unauthorized weapons at their surveillance station.

In order to understand the number of violations and the high incidence attributed to Israel it is necessary to visualize the location of the sensor fields and the buffer zone. Where the eastern boundary of the buffer zone and its sensor fields end, the Israeli limited force zone begins. The Egyptian limited force zone was not similarly situated. It was five miles from the sensor-monitored buffer zone. This five mile zone was occupied by the United Nations Emergency Force Buffer Zone. If Egyptian forces made a shallow incursion, it would not be detected because the Egyptian boundary line was five miles beyond the detection range of the sensors. Instead, these incursions might or might not be detected by the UNEF forces. If an Israeli patrol crossed the boundary, it would immediately activate the sensors resulting in a violation. The result is that Israel had the greatest number of violations from personnel,

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[80] Carter, J. Kontos, C. (April 16, 1980). Ninth Report to Congress: The United States Sinai Support Mission. p. 7. Obtained from the C. William Kontos Collection, Gerald R. Ford library, National Archives.

vehicles and aircraft. It is also possible that some violations were intentional to test the alertness of the SFM, the sensitivity of the sensors, and the reaction time by which the intrusion would be reported. The maximum penetration of the sensor fields by unauthorized vehicles or personnel was 300 meters while the average was 220 meters.[81]

3. False Activations

Many activations occurred as part of the normal day's activities as authorized vehicles and personnel moved to and from the Egyptian or Israeli watch stations. The small-arms training of the Israelis and construction blasting of the Egyptians also caused activations. However, numerous other activations occurred but investigations determined that these were due to weather, animals, seismic activity or Bedouins. Very heavy winter fog during the morning and evening sometimes was enough to activate the sensors. Rodents were also a significant cause of activations. When the workers from the SFM emplaced sensors, their perspiration would smear on the sensors and their electrical cables. The rodents would be attracted to the smell of the sweat and gnaw on the cables. This problem was alleviated by having all personnel wear work gloves. Despite these

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[81] Carter, J., Kontos, C. (October 13, 1977). Fourth Report to Congress: The United States Sinai Support Mission. p. 5. Obtained from the C. William Kontos Collection, Gerald R. Ford Library, National Archives.

problems failed sensors were replaced within 24 hours and a sufficient number of sensors were emplaced to ensure redundancy. The result was that "sensor equipment loss due to failure approximated 5%."[82] Wild herds of gazelles, camels and flocks of birds also caused problems.

The most significant problems were with Bedouin Tribes that were indigenous to the area and traveled without respect for borders, sensors or United Nations patrols. While officially citizens of Egypt, all parties recognized them as a group unto themselves and did not treat their activities as a "treaty violation." However, the Bedouins did cause difficulties for the Sinai Field Mission. One of the most significant was thievery. The Bedouins had battery-powered televisions that were compatible with the 12 volt car batteries used by the video cameras at Giddi West. It was not until these were locked in makeshift battery cases that the thefts subsided.

4. Alternatives to Sensors

The Sinai Field Mission conducted a study to identify alternative technologies and procedures for use in the Sinai. The purpose was to reduce or eliminate the number of personnel required to operate the watch stations. The study

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[82] Vannoni, M. (1996). Sensors in the Sinai: A Precedent for Cooperative Monitoring. Sandia National Labs. p. 12.

was conducted with the advice and assistance of the Mitre Corporation. Four alternative courses of action (COAs) were identified. Course of action one was a centralized detection of intruders where all sensor alarms were transmitted to the base camp. An investigation would be conducted by dispatching a jeep or airborne patrol. The second course of action was a centralized detection of intruders where the sensors would be transmitted to the base camp and the intruder would be identified using remote controlled video cameras. Course of action three was the substitution of Ground Surveillance Radar (GSR) for the sensors. The GSR could maintain a wider area of observation than the sensors and the GSR would transmit an alarm to a watch station if a detection occurred. Personnel at the watch station would then investigate. Course of action four required a centralized radar detection system and the use television cameras to identify the intruder.

The SFM determined that the first course of action was unacceptable. This was because the Sinai Disengagement Agreement allowed a large number of vehicles to pass through the monitoring zone on a regular basis. The monthly average was 6,000 vehicles. Many of these vehicles belonged to the United Nations Emergency Force and others belong to the Egyptians and Israelis. All of these vehicles and movements were authorized to support travel to surveillance stations

in the buffer zone and patrols. This quantity of vehicles and the alarms they produced would require the dispatch of literally thousands of vehicle and air surveillance missions to investigate the sensor alarms. The third course of action of substituting radar for sensors did not provide a significant advantage. It would require the same number of personnel. In addition theimprovement of detections was minimal and the cost of the radar was much greater than the sensors.

Course of action two and four did show promise. Both involved the removal of the watch station operators and centralized monitoring of the alarms from the base camp. Course of action two continued to use sensors and COA four substituted radar for sensors. The identification of intruders would them be made by remote controlled video cameras. Further study determined that neither course of action could be implemented. This was because the text of the basic agreement required "American civilian personnel to operate the three watch stations and provide continuous tactical surveillance." While the study was unsuccessful overall, it did result in the use of video cameras at Giddi West, which was beyond the line of sight of the base camp.

E. ANALYSIS

The use of sensors in the Sinai was successful. The principle objective was to use information provided by the sensors as a confidence building measure to promote peace and further negotiations. Up-to-the-minute reports of activity within the Sinai enabled the SFM to reduce the possibility that misperceptions of hostile intent might spark a chain of escalation resulting in a return to open conflict.

The US role in the Sinai and it's ability to achieve success was due to a "unique set of circumstances". The circumstances were: (1) The critical role played by the US in the negotiations, (2) the geography of the Giddi and Mitla passes which allowed control of a wide area to be reduced to the control of two passes, (3) the sterile buffer zone which was generally uninhabited, and (4) the absence of terrorist activity. It is important to recognize that those circumstances, which made the effort possible, may not be present in other areas. The most important of these factors was the absence of terrorist activity. This was primarily due to the desire of Egypt and Israel to achieve a lasting peace. Both countries had willingly signed the peace agreement and took the necessary steps to support the security arrangements.

The successful employment of sensors in the Sinai serves as a model of how sensor technology can be used to support peacekeeping operations. Had the US not participated in the Sinai peace effort a stable peace in the Sinai would not have been achieved. President Ford stated before Congress that, "the early warning system in the Sinai is an important investment in Peace...continuing presence of the system provides in itself an important contribution to stability in the area and to the creation of a climate of confidence so necessary for further progress toward a just and durable peace."[83] Sensor monitoring also received accolades from both the Egyptians and Israelis. "One senior Israeli official suggested that the SFM could serve as a model for use in other Mideast trouble spots, such as the Golan Heights or the West Bank." [84]

The capabilities of the sensors were dictated by a set of self-imposed limitations. First, the sensors would be monitored by civilian personnel who had a minimum of sensor training or experience. Second, the technology would be used for peacekeeping operations. Third, it was necessary to share the knowledge and capabilities of the technology with

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[83] Khisheib, U. (May 17, 1976). A Lonely Outpost Where Yanks Guard Against Sinai War. US News and World Report. p. 54

[84] US Congress, Senate. (June 6, 1977). An Evaluation of the US Early Warning System in the Sinai. Washington D.C., GPO. p. 6.

both the Israelis and Egyptians to assure them that the technology would be successful. However this was done without without compromising key aspects of the technology which would have allowed either side to *spoof* the sensors. Finally, while the technology could be monitored remotely, the peace agreement required an American presence as a buffer between the parties. These self-imposed limitations required a force of approximately 170 personnel to monitor the Sinai and perform support functions. However, the unique geography of the Sinai enabled the SFM to reduce a large geographic area to the control of two key passes.

These passes which comprised 620 square miles could then be monitored 24 hours a day by 43 civilian personnel. While infiltrators of the sensor fields were not killed or bombed they were targeted and intercepted by a quick reaction force of United Nation's peacekeepers. This translated to a form of *precision engagement* appropriate for peacekeeping operations.

As noted earlier, precision engagement has five component parts: Targeting, Command and Control (C2), the ability to achieve a desired effect, the ability to assess the level of effectiveness achieved (BDA) and the ability to re-engage when required. In order to achieve these requirements the ground sensors had to meet a number of criteria. (See Figure 3.3)

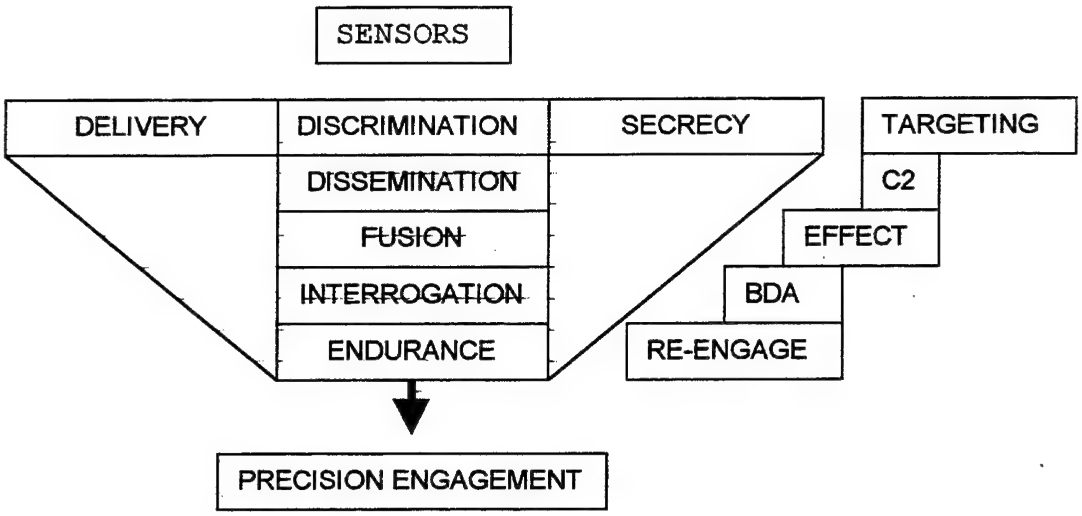

Figure 3.3 Sensor Criteria for Precision Engagement

1. Targeting

For targeting, sensors had to be delivered to a location where they could sense the target. Second, the sensors had to be covert in location and key aspects of the technology to prevent the enemy from destroying them or innovating around them. Third, the sensors had to be capable of discriminating between a variety of targets.

a) Delivery

All of the sensors required for monitoring the Giddi and Mitla Passes were emplaced in four days. While the capability of air delivery was available, it was not required. Instead, all sensors were emplaced by hand. This method of delivery was easy and inexpensive. However, it was

only possible due to the lack of hostile activity in the Sinai. While the delivery of sensors was successful, the location the sensors were delivered to was problematic.

Sensor fields were placed adjacent to the Israeli Limited Force Zone. The sensors fields ended five miles away from the Egyptian Limited Force Zone. This resulted in numerous unintended violations by the Israelis as their air and ground patrols bumped against the boundary. On the other hand, the Egyptians were not charged with unintended intrusions largely because their forces would have been detected by the UNEF before reaching the sensor fields. This provided the Egyptians with a political advantage in which they could point to the large number of Israeli intrusions and accuse them of military aggression. Extending the sensor monitoring an additional five miles until it joined the border of the Egyptian Limited Force Zone might have prevented this.

b) Secrecy

In the Sinai, both overt and covert sensors were used. Seismic, acoustic and magnetic sensors were covert and were buried below the surface of the earth where they were not visible. They were so covert that some of the SFM personnel that emplaced the sensors had trouble finding them to change the sensor batteries. This prevented an

intruder from determining the location of the sensors and infiltrating through a blind spot in the sensor coverage. It also prevented an intruder from destroying the sensors or collecting them to gain intelligence on the sensor capabilities. However, the sensors were not as secret as might be desired. The communication frequency of the sensors was not encrypted and the possibility existed that it could be jammed. The sensor transmission could also be intercepted or detected because of its transmissions. While these possibilities existed, these types of innovations by an enemy did not occur. One aid in preventing this was the short duration of a sensor transmission. If a sensor activated, the duration of the alert would be burst to the watch stations in seconds making it difficult to triangulate its location.

Overt sensors were also used. The video cameras and Infrared break beams were an overt method of sensing. While these sensors performed a valuable function, their overt presence enabled intruders to disrupt them. The most common example was provided by the Bedouins. While this was immediately detected by the SFM personnel, it became a constant problem until the batteries were secured in locked containers. This disrupted the monitoring efforts of the SFM until the batteries could be replaced.

Another issue related to the secrecy of the sensors was the technology. All of the sensors used were unclassified. If the sensor technology had been compromised, it would not have been a major concern. The fact that the sensors were unclassified actually made the operation more successful because the sensor information could be shared with both parties. This was used to convince both parties that the sensor monitoring would be successful. In this case, the location of the sensors was secret but the technology was not.

c) *Discrimination*

The sensors used in the Sinai could detect and discriminate between vehicles, tanks and personnel. Multiple types of sensors were used in each of the sensor fields to detect infiltrators. Often an infiltrator would be detected by pressure, acoustic, seismic, infrared, magnetic and other means all in a matter of minutes. Detection was especially effective at night when the Sinai was relatively uninhabited with the exception of Bedouins. This enabled a rapid detection and discrimination of activity. However, during the day and at other scheduled times there was a large amount of traffic within the Sinai. The Sinai Interim Agreement allowed for the movement of personnel to electronic surveillance stations operated by the Egyptians

and the Israelis. It also allowed for the movement of United Nations Forces within the buffer zone. These movements resulted in thousands of sensor activations, which were part of authorized activity. During these periods, the sensors could detect activity but they could not differentiate between authorized and unauthorized activity. This could only be accomplished by the watch station personnel.

During the course of the operation, remote controlled video cameras were introduced to allow remote discrimination of activity. This reduced the need for a large number of personnel to man watch stations and allowed a centralized discrimination between authorized and unauthorized activity. As technology advances an improvement would be to combine remote video or optical technology with each sensor. This would enable monitoring personnel to channel-surf between sensors, that had detected activity. Discrimination of targets could then be accomplished remotely and with greater precision.

2. Command and Control

The SFM had to provide C2 over a large amount of sensor information and disseminate it to multiple nations and forces to increase their chances of mission success.

a) Dissemination

In the Sinai, precision engagement consisted of

the immediate detection of intruders ranging from individual vehicles to personnel. Once a detection occurred, an investigation would be conducted. If analysis confirmed an unauthorized intrusion, notification would be made within five minutes to all parties. A report would also be transmitted to UNEF patrols that would interdict the intruder. Notification of the Israelis, Egyptians and US National Security Council was not automated. While this would have made notification faster, it was not possible due to the requirement to discriminate between authorized and unauthorized activity.

While the requirement for an investigation increased the time requirement, it did not inhibit interception of infiltrators. During the course of the monitoring, the maximum penetration of the sensor fields was 300 meters and on average was 220 meters. Air and space surveillance assets could not provide this capability on a 24-hour basis nor could they provide the resolution necessary to detect intrusions by individual soldiers.

A unique aspect of the Sinai monitoring was the use of civilians. The use of civilians as a proxy for US military forces required the use of *Information Brokers*. While American civilians were sufficient to conduct the monitoring and day to day operations, they did not represent the US government. The value assigned to the information

created by the sensors was dependent on a recognized third party. This party was the United States Government. The role of information brokers was satisfied by using State Department officers. These officers were responsible for the authenticity, accuracy and integrity of the information. Authenticity was achieved by having an officer personally sign a report of a violation guaranteeing its authenticity. Accuracy was a function of using teletypes, which would produce a written record of a report. Written records were preferred because they allowed less opportunity for misinterpretation than verbal reports. This is particularly important, as they had to be translated by the receiver. Integrity was achieved by sending the message directly from the base camp to the State Department liaison officers at the Egyptian and Israeli surveillance stations. Hand delivery of the reports prevented the possibility of the report being modified.

3. Effect

The ability to achieve a desired effect against a target is not restricted to the sensor itself. It encompasses accurate targeting, the size and type of force allocated to the mission and the type and quantity of munitions expended against a target. In order to meet these requirements, various types of sensor data must be fused

together to provide a complete picture of the target and the battlefield.

a) *Fusion*

In the Sinai, sensor data was fused into a synoptic picture. Each infiltrator was detected by a variety of different sensors with different capabilities in a matter of minutes. This information was received by the watch station personnel and an investigation was conducted using remote controlled video cameras, or other optical devices. The different methods of detection were then combined to form a complete picture of the detected activity. In the Base Station, all of the sensor readings were immediately displayed on an electronic map, which would indicate individual sensor activations using small light bulbs. This ensured that the target was detected rapidly and by a variety of different methods to minimize the chances of a false activation as well as to develop a complete picture of the activity. One of the distinct advantages of the electronic map was that it would constantly update itself according to the sensor activations as opposed to a photograph which was merely a snapshot in time.

4. Bomb Damage Assessment

BDA is the ability to assess the level of effectiveness of an airstrike or attack by determining if a bomb or

munition has hit its target and, if hit, what effect that achieved. The use of sensors in a BDA role is an effort to interrogate a target for emissions which would indicate a live or dead target.

a) Interrogation

The ability to interrogate a target in the Sinai is a missing variable. Unauthorized activity in the Sinai consisted of Israeli ground patrols and aircraft which accidentally strayed into the sensor fields. Other violations of the Sinai Interim Agreement were for unauthorized weapons at the watch stations. None of these targets were fired upon. However, unauthorized intrusions were rapidly intercepted by the UNEF. It is also important to note that the monitoring of the Sinai was peacekeeping not combat. In the Sinai, the Measure of Effectiveness (MOE) was interception not destruction. In this regard, the operation was entirely successful. While the ability to interrogate a target was not present, the SFM did maintain a variety of sensors both unattended and attended, which could have assessed destruction of a target. Destruction would have been determined by the absence of a seismic, magnetic, infrared, or pressure activation combined with observation by video or other optical means. Again, the capability to

combine an optical capability with each sensor would have increased the interrogation capability of the sensors.

5. Re-engage

Assessment will invariably conclude that some targets have escaped destruction or have sustained only minor damage, which allows them to continue operating. This necessitates the ability to reengage a target when required. Central to this requirement is the endurance of a particular sensor. Long endurance will enable a sensor to support a second strike against the same target if required.

a) Endurance

At the onset of the Sinai monitoring, battery technology had advanced enabling the sensors to operate as long as one year on the same battery. This greatly increased the cost effectiveness of the sensors and reduced the maintenance requirements for long term monitoring. It also enabled the ground sensors to monitor activity in the Giddi and Mitla passes 24 hours daily. Monitoring was continuous and effective during all light conditions as well as during periods of cloud cover or inclement weather.

IV. DESERT STORM

There is nothing more exhilarating than to be shot at without result

-Winston Churchill

A. INTRODUCTION

In the Gulf War, a great deal of *precision engagement* was conducted. However, it was conducted in the absence of Unattended Ground Sensors. Precision engagement was enabled through the use of satellites and aircraft sensors. My purpose in using the Gulf War as a case study is twofold: First, to identify what failures in precision engagement occurred because of an over-reliance on satellites and aircraft sensors; second, is as a tough test for ground sensors. It is a tough test because the Gulf War is viewed by many as the most successful war ever prosecuted by the United States. The war was short, few casualties were incurred, and much of the success of the war could be traced back to the use of airpower and precision guided munitions. Additionally, the United States enjoyed many advantages in the area of *precision engagement*. To name just a few, the war was conducted in the desert where there were few places for the enemy to hide. The US had the greatest number of reconnaissance satellites in orbit in its history. The establishment of a coalition also provided the US with the

ability to employ its air reconnaissance assets in the airspace of bordering countries. Given these advantages, was there a role for UGS?. Was there a gap in *precision engagement* which UGS could have filled?

B. BACKGROUND

Iraq invaded Kuwait on 2 August 1990 with an armored and mechanized assault consisting of three Republican Guards divisions. Iraq's leader, Saddam Hussein wanted to extend his influence in the Gulf region and gain control over Kuwait's rich oil reserves and wealth. Saddam also wanted greater access to the Persian Gulf. Iraq had long maintained the desire to gain control of the Warbah and Bubiyan Islands which were situated along the Khawr 'Abd Allah waterway. Iraq's other waterway the Shatt Al-'Arab was clogged with the remnants of sunken vessels and dangerous munitions from the Iran-Iraq War. Saddam justified his actions by accusing "Kuwait and the United Arab Emirates of complicity with the United States to cheat on oil production quotas."[85] Saddam argued that an over production of oil had deflated its price causing serious harm to Iraq's economy. This statement was made despite the fact that Iraq's economy had long been bankrolled by Kuwait and other Arab countries through generous long-term loans and support.

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[85] Department of Defense. (April 1992). Conduct of the Persian Gulf War. Washington D.C., GPO. p. 5.

Kuwait quickly crumbled under the weight of Iraq's superior military force. The defeat was quick, as the Kuwaiti government had reduced its military readiness posture from a 100% alert to 25% just prior to the invasion. This was done by the Kuwaiti government in a political attempt to reduce tensions between the two countries. As the invasion unfolded, the greatest fear of international leaders was that Iraq would merely pause in Kuwait and then invade Saudi Arabia. On 3 August, US President George Bush warned Saddam Hussein not to invade Saudi Arabia. Despite this warning, Iraqi armored forces continued to buildup along the Saudi Border. Even more ominous was the withdrawal of the Republican Guards forces from Kuwait and their replacement with regular army divisions from Iraq. These regular forces occupied defensive positions along the Kuwaiti border while the Republican Guards conducted resupply. This freed the Republican Guards for an invasion into Saudi Arabia.

In a few days following the invasion, Saddam quickly assembled a force of approximately 200,000 soldiers and 2,000 tanks in or around Kuwait. It quickly became apparent to President Bush that an invasion of Saudi Arabia was imminent and the only option immediately available was land-based air power. The navy could move its carriers closer into position but they did not have the range or quantity of

firepower necessary to stop an invasion. While ground forces were obviously needed, it would take months to deploy a force capable of stopping an Iraqi Armored advance. On 6 August, King Fahd bin Abd al-'Aziz Al Sa'ud of Saudi Arabia requested military reinforcements from the international community.

1. CENTCOM

The task of reinforcing Saudi Arabia fell to the US Central Command (CENTCOM). CENTCOM was the newest of all the regional commands and was commanded by General Norman Schwarzkopf. Its area of responsibility included Northeast Africa, the Middle East and Southwest Asia. General Schwarzkopf immediately responded to President's Bush's order to reinforce Saudi Arabia. CENTCOM deployed squadrons of F-15 aircraft, and the 82d Airborne Division, a rapid deployment force. When the invasion occurred, CENTCOM was the only regional command that did not have a headquarters within its area of responsibility. CENTCOM had its headquarters at MacDill Air Force Base in Florida. CENTCOM had to deploy not only its forces, but its headquarters as well.

2. Desert Shield

The initial military response to the invasion of Iraq was defensive and became known as Operation Desert Shield. The first military forces to deploy to Saudi Arabia were Air

Force Squadrons and Navy aircraft carriers. However, the US Army would be close behind. While aircraft could deploy quickly, the decision was made not to attack. The danger was that this might cause the Iraqis to invade sooner rather than later. Instead, Operation Desert Shield *would draw a line in the sand* and establish an air and ground defense against an Iraqi invasion. The initial ground force would be the 82d Airborne Division. This division had limited anti-armor capabilities and could be expected to take high casualties when fighting tanks. However, CENTCOM reasoned that by augmenting them with aircraft in an anti-armor role they could provide an initial defense.

General Schwarzkopf's priority for deployment into theater rapidly became heavy forces such as armor, mechanized infantry and artillery. In order to achieve the buildup of these types of forces, General Schwarzkopf had to deploy them without much of their supporting assets. CENTCOM achieved this by developing support agreements for food, fuel and other resources from Saudi sources. However, this meant leaving other military forces behind as well. "Early in Operation Desert Shield, the build-up of in-theater intelligence capabilities was intentionally and rationally restricted by General H. Norman Schwarzkopf."[86] This was

[86] US Congress. (August 16, 1993). Intelligence Successes and Failures in Operations Desert Shield/Storm. Washington D.C., GPO. p. 4

done with the reasoning that supporting assets such as military intelligence forces would be easily overrun by the Iraqi's if they were introduced into theater too soon. This decision was also made in recognition of the great number of satellite and air surveillance capabilities within the US military inventory. However, "[t]he absence of early deploying tactical intelligence collectors meant that theater commanders were initially forced to rely heavily on national intelligence systems such as satellites, as the primary intelligence collectors."[87]

While this supported General Schwarkopf's intent, it had two side effects. First, it reoriented the grand majority of the nations strategic surveillance assets on Iraq. In fact, "for the first time, the Soviet Union took a back seat to another part of the world as an intelligence collection target."[88] Second, the lack of tactical intelligence limited General Schwarkopf's knowledge of the enemy.

While, CENTCOM's intelligence staff could visualize much of the battlefield, it was the equivalent of "searching New York City through a soda straw". Sattelites did not provide a wide field of view and intelligence was not available on an up-to-the-minute basis. Furthermore, It

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[87] Ibid, p. 4

[88] Ibid, p. 5

lacked the detail necessary to support tactical commander's on the ground. While Satellites could locate major units they could not detect and report targets in real-time, effectively conduct battle damage assessment or provide the resolution to detect infantry soldiers. This led General Schwarzkopf's staff to develop a worst case estimate in the absence of detailed information on the enemy. In effect, Clausewitz's observation became true, "that military commanders tend to opt for a worse-case analysis under conditions of uncertainty."[89] The Iraqi Army was painted as being much stronger, and in some cases larger than it really was. This led General Schwarzkopf to deploy approximately 50% of the United States Army, 25% of the Navy, 25% of the Air Force, and 66% of the Marine Corps to Saudi Arabia. The time required for air and sealift of these forces caused a significant delay before executing a ground offensive.

While the military intelligence forces from the Army were initially left behind, it is not entirely clear that their deployment would have significantly changed the war effort. At the time of Desert Shield, the Army did not have a surveillance analysis capability. The personnel required for imagery interpretation from satellites and aircraft had

[89] Handel, M. (Ed.) (1990). Intelligence and Military Operations. Portland, Frank Cass & Co. Ltd. P. 80

largely been cut from an Army role because it was widely believed that they were no longer needed. Technology, it was argued had advanced to the point where imagery could be analyzed by a centralized facility and the digitized results transmitted to the user.

At the tactical level, much of the army's doctrine had outpaced the ability of military intelligence to keep up or support. While the Army had a variety of systems for collecting intelligence, they required an extensive amount of time for set-up and tear down. Even military intelligence assets that were mounted in M113 armored personnel carriers could not keep pace with the army's M1 tanks that could travel 40 miles per hour on a desert battlefield. These inadequacies and the lack of tactical intelligence led to a *capabilities focus* for General Schwarzkopf. Instead of relying on intelligence to determine the appropriate military response, the lack of intelligence led military planners to develop an offensive plan based on capabilities such as air power to attrit the Iraqi tanks.

C. TACTICS

The initial tactics developed by CENTCOM were defensive and linear and were designed to provide an air and ground defense against an Iraqi invasion. This defense would provide the time necessary to prepare an offensive if

required. It would also allow time for the development of a coalition of military forces from different countries that would lend international support for the operation. The offensive plan named Desert Storm, would begin with a protracted air war that would establish air supremacy over Kuwait and Iraq. Air strikes would then be used to attrit 50% of the enemy's tanks, armored personnel carriers and artillery. Once this statistical goal had been achieved, coalition ground forces would begin their ground offensive. Critical to all phases of Desert Shield and Storm was the use of space and air surveillance for early warning of an invasion, targeting of the Iraqi forces, command and control (C2) and battle damage assessment (BDA).

1. Air and Space Surveillance

Space and air surveillance systems are divided into three segments: the space or air segment, the control segment and the user segment. The space segment consists of satellites, while the air segment consists of aircraft. The control segment refers to the ground stations, which direct the satellites, as well as the satellites which support ground to space communications. The user segment consists of the personnel and receiving stations that utilize the imagery collected and analyzed by the control segment.

a) Space/Air Segment

At the time of Desert Shield, the US had an unprecedented number of satellites available for surveillance of Kuwait and Iraq. The US had three of the older KH-11 (Keyhole) imagery satellites and one LACROSSE radar imaging satellite in orbit. In addition, the US had a variety of other satellites to support communications and collect weather data. There was also an undefined number of Defense Support Program Satellites (DSPS), which could detect missile launches. While a variety of surveillance aircraft were available, General Schwarzkopf prohibited them from conducting overflights of Iraq before the start of the Air-war. This was done because of their vulnerability to Iraqi air defenses and the concern that their use might hasten an invasion by the Iraqis.

The space segment had many limitations. First, while there were three optical satellites that could pass over Iraq, there were periods as long as five hours where none could observe Iraq or Kuwait. Having only one LACROSSE satellite available meant that radar imagery would only be available every 12 hours. With these resources it would often take multiple passes to develop accurate imagery or intelligence on a target. "According to a DIA official, only

the enemy's large static defense strategy allowed us totrack his numbers and disposition with acceptable accuracy." [90]

Second, the satellites themselves had limited capabilities. KH-11 satellites were good during the day but had little value at night. This combined with weather limitations from clouds or man-made oil fires prevented good imagery of selected areas. In addition, heat and radar contrast made it difficult to differentiate between targets or pinpoint their locations. While the optical (KH-11) satellites had resolution of approximately 10 centimeters, the LACROSSE provided a resolution of 1 meter. As a result, the KH-11 could detect if a bomb had penetrated the roof of a bunker but a LACROSSE could not. However, the LACROSSE could detect targets through clouds, which the KH-11s could not.

Third, satellites are a top-down system. They were good for looking at the rooftops of buildings but not at seeing what was inside or covered by shelters. Iraq's development of underground complexes and its use of sand and bunkers to cover its tanks further limited their value.

Fourth, Iraq made extensive use of decoys and deception measures. Iraq had purchased a great amount of satellite imagery of Iraq, Saudi Arabia and Kuwait prior to

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[90] Richelson, J. (1995). The US Intelligence Community. Boulder, Westview Press. p. 157.

the war. Some of the coverage was the equivalent of US capabilities purchased from the Russian and French governments and some was from commercial sources. This knowledge of satellite capabilities coupled with information about US satellites enabled Iraq to plan its operations, while determining when satellites could be expected to overfly Iraq. This knowledge enabled the development of decoy sites and vehicles as well as the knowledge of when to hide or disperse capabilities.

Fifth, the targeting effort of the coalition required months of satellite coverage. Had Iraq immediately invaded Saudi Arabia, the satellite coverage would not have been possible.

Sixth, the Gulf War was unique as it occurred in the desert. There was little to prevent overhead observation of the entire region during the course of the war. However, if the conflict had been conducted in Southeast-Asia satellites would have been foiled by the cover and concealment of triple canopy jungle.

Finally, satellites operate in a standard orbit and cannot be dispatched to cover events on short notice. In order to provide the necessary coverage of a selected area, satellites will often have to be re-tasked. Given the limited amount of fuel each satellite carries, multiple changes to a satellites' flight path may reduce its life

span. Additionally, the willingness to re-task will be based on a cost-benefit analysis in which its current orbit may be deemed more important than the requested orbit. Inevitably, one priority will outweigh another.

In air surveillance many aircraft with different types of sensor capabilities were employed by the US and coalition forces during the Gulf War. Many focused on the detection of aircraft while others concentrated on electronic signatures from radar and communications. Relatively few were capable of detecting ground targets that were relevant to tactical ground force commanders. These commanders were concerned with tanks, armored personnel carriers, Scud missile launchers and the disposition of enemy troops on the battlefield.

Reconnaissance aircraft consisted of F-16s with *Lantirn* Infrared navigation pods, Air Force OA-10s, OV-1D and RV-1D Mohawks and F-14Ds with Tactical Air Reconnaissance Pods (TARPS). These aircraft flew hundreds of missions during Desert Storm. Some of these aircraft required pilots to fly low with binoculars to spot targets while others used onboard cameras and sensors for detection. Some contributed in minor ways to targeting and battle damage assessment or intelligence gathering. While the cumulative effect of these aircraft did contribute to the

war effort, their individual contributions were negligible. This was due to their inability to conduct reconnaissance at night or their inability to transmit imagery in real time. The greatest contributions in the areas of detection, targeting and intelligence for ground targets came from dedicated tactical surveillance aircraft. Tactical aircraft used in the Gulf War consisted of the JSTARS, the U2/TR-1 series aircraft and the RF-4C. However, these aircraft were only used during the air war and not during the preparation for the war. "Official US histories have confirmed that the US was unwilling to risk manned airborne collection platforms like the RF-4C, U-2, and TR-1 over Iraq until a coordinated air operation began."[91] This decision was also made to avoid the possibility that the loss of an aircraft might start the war before CENTCOM was prepared to fight it.

b) Space Control Segment

Control of the satellites was centralized for a number of reasons. First, the same satellite that took pictures of Iraq would also take photographs of other parts of the world as it continued its orbit. However, on a priority basis a satellite might be re-tasked to a different orbit. Second, satellites consisted of the National Technical Means (NTM) for intelligence and surveillance.

[91] Ibid, P. 296

They were not designed or organized to support tactical commanders on the ground. The doctrine for space support to the military depended on a high to low dissemination. Analysis was conducted by a centralized facility, with the digitized results disseminated to the user.

The path of the majority of satellite imagery would start with the satellite. It would then be sent to a Satellite Data Systems (SDS) satellite, then to a ground station, followed by retransmission to a Defense Communications Satellite (DCS). The transmission would then be passed to Ft Belvoir in Virginia, over to the National Photographic Interpretation Center (NPIC) for processing, then to a communications satellite and then to the user. While most parts of this process could be accomplished in minutes, the bottleneck would occur at the NPIC. On the other hand, if the transmission was immediately relayed to a ground terminal in the Gulf, the bottleneck would occur at the analysis section in theater.

Tactical military commanders had greater control over the air segment. However, the inability to use the systems before the start of the air war greatly limited their value. While there were a variety of types of aircraft, most relied on the use of film, which could not be transmitted in real time. Dissemination occurred after the plane landed and the film processed and analyzed. After

that, it was transmitted by a secure fax or transported by courier to the user.

c) User Segment

The dissemination of imagery obtained from satellites did not become a significant problem until the start of the war. Each of the different services as well as different commands employed a variety of systems for secondary transmission of imagery. These were secure fax machines that would enable the sharing of imagery obtained from air reconnaissance aircraft and satellites. CENTCOM used the Digital Video Imagery Transmission System (DVITS) which was purchased by the Defense Intelligence Agency. Only a few of these systems were procured and shipped to the Gulf before the war ended.

The Air Force had the Tactical Digital Facsimile (TDF). This machine was slow to transmit, had poor resolution, and did not have an automatic error correction capability. As a result, if an image was not received correctly, the entire image had to be resent. The price tag of the TDF was also a problem as each machine cost $688,000. The Navy and Marines used the Fleet Imagery Support Terminal (FIST). During Desert Shield, other types of SIDs were deployed as well. The Navy, Marines, Air Force and Army deployed 12 different types of Secondary Imagery

Dissemination Systems (SIDs) to the Gulf. Only four of these were able to communicate with each other. "These were not compatible because they were not equipped with the national imagery transmission format or common communications protocols. The resulting hodgepodge of systems injected time delays into distribution of time-critical imagery and imagery derived intelligence."[92]

As noted, the first intelligence bottleneck was analysis. The lack of interoperable SIDs systems in the Gulf became the second. After processing at the NPIC, "Intel data could be passed in real-time or near real-time [from Washington] to J-2 [intelligence] in-theater, but because of a lack of common imagery data dissemination systems, the component commands as well as forward-deployed units could not always gain timely access to such imagery."[93] The magnitude of the problem did not become readily apparent because of the short duration of the war.

During Desert Shield, military planners had the benefit of 5 and 1/2 months in which to develop target folders inserting the most accurate and up to date imagery for use during the air campaign. During this period, the

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92 Clapper, J. (September 1991). Desert War Was Crucible for Intelligence Systems. Signal. P.77

93 US Congress. (August 16, 1993). Intelligence Successes and Failures in Operations Desert Shield/Storm. Washington D.C., GPO. p. 14

lack of adequate SIDs was satisfied by using couriers who could transport the imagery by plane to the Gulf. However, once the air campaign started, the 18-hour trip from the US to the Gulf rendered much of the imagery unusable because the battlefield had changed considerably between the time the photos were taken and delivered. While the initial three days of the air campaign benefited from imagery, "after three days, however, target imagery and current intelligence on mission performance decreased dramatically, and what did arrive was often late, unsatisfactory or unusable."[94] The problem became so chronic that, "One wing reported that a squadron flying over 1,000 missions received only four images after D+3, none in useable form."[95]

2. The Air War

While an accurate plan had been developed for targeting fixed sites throughout Iraq and Kuwait, the targeting problems for the Air Force occurred at the tactical level. The JSTARS, TR-1 and U2-R aircraft were required to conduct surveillance from a standoff distance of 75 kilometers behind the front lines. This was done to prevent their loss to Iraqi air defenses. Even operating under this limitation, some of the aircraft could still observe as deep as 150

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94 Ibid, p. 14.

95 Cordesman, A., Wagner, A. (1996). The Lessons of Modern War Volume IV: The Gulf War. Westview Press, Boulder. p. 290

kilometers into Iraq. While this is an exceptional capability, it did not provide the range necessary to observe all of the areas from which Scud missiles were being launched. It also did not support the conduct of targeting or bomb damage assessment of tactical targets deep in Iraq.

Problems also occurred as the range limitations of the aircraft sensors required overflight agreements with Syria in order to achieve a broader coverage of the area of operations. Syria approved the overflights because of its membership in the coalition. However, if the requirement had been in Jordanian airspace this would not have been possible.

The U2-R aircraft had the most limited range while the TR-1 and JSTARS could range for 150 kilometers. While these aircraft could conduct surveillance of a large area, detailed targeting was achieved by concentrating on detailed 4 by-4 kilometer grids. Both systems were incapable of detecting and targeting stationary vehicles and both required a force package of electronic jamming aircraft and fighter escort for protection. While the JSTARS aircraft had advanced capabilities, only two experimental aircraft existed at the time of the air war. These aircraft conducted 44 air missions over 41 days. The time spent in the air averaged 12 hours or less preventing the aircraft from providing a true 24-hour capability for targeting.

The RF-4C, a Vietnam era aircraft provided reconnaissance at the tactical level as well. The RF-4C was not limited to flying from a standoff distance because it had a limited range. Instead, it would be sent forward as part of a force package of electronic jamming aircraft and fighter escort to increase its survivability. While the RF-4C could take detailed film for reconnaissance and bomb damage assessment, the film had to be processed upon return to its base. This prevented it from providing a real time method of targeting and assessment.

3. Bomb Damage Assessment

The lack of doctrine and systems to conduct Bomb Damage Assessment was one of the greatest intelligence failures of Desert Storm. The United States military had not invested in BDA technology or training in the years since the Vietnam War. Analysts from that conflict had long since retired and many of the lessons learned had been forgotten. The lack of BDA doctrine was not an accident. Instead, "it was sometimes assumed that improved targeting and more lethal and smarter weapons largely eliminated the need for detailed hard data on damage effects. This seems to have been a reason that CENTAF and the Special Planning Group initially decided not to use reconnaissance aircraft to cover targets that Coalition air forces had already struck during the war."[96]

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[96] Ibid, p306

In preparation for the air war, General Schwarzkopf made two important decisions that would have a profound impact on the role of bomb damage assessment. First, he dictated that the ground war would not be launched until the air war had attritted 50% of Iraq's tanks and armored personnel carriers. Second, "General Schwarzkopf sensibly chose to have the Army-which would have to face any surviving tanks, APCs and artillery pieces-rule on how many pieces of equipment air power was knocking out."[97] However, the Army component of Central Command (ARCENT) was not trained to conduct proper bomb damage assessment.

The ARCENT Intelligence officer (G-2) began by establishing percentages for how effective different types of aircraft and weapons systems were. For example, "the ARCENT G-2 determined, that he would count 75 percent of all the kills reported by A-10 crews. The A-10 does not have a gun camera. But A-10s normally operated in pairs and ARCENT decided the trailing pilot generally had a good enough view of what the lead pilot accomplished to accept three-fourths of all claims. Other percentages were adopted for other pieces of equipment."[98] However, during the air war, "A-10 pilots made exaggerated claims, and US CENTCOM initially

[97] US Congress. (August 16, 1993). Intelligence Successes and Failures in Operations Desert Shield/Storm. Washington D.C., GPO. p.18

[98] Ibid, p19

directed that all such claims be automatically discounted by 50%. As time went on, however, imagery led the ARCENT analysts, assessing damage to Iraqi ground targets, to discount their claims by 66%, and later analyses of U-2 flight data, gathered over the battlefield immediately after the war, indicated that even the 66% discount may still have been too low."[99]

The same types of problems occurred with other aircraft throughout the air war. In some cases, the coalition air force began double and triple counting the same tank as being killed because attacking aircraft had a tendency to attack the same vehicle more than once. Other problems were a result of tactical doctrine. Pilots would typically attack the lead and trail vehicle of a convoy. The Iraqis would then abandon the vehicles in the center of the column and these would be counted as dead. In still other cases, a vehicle would be damaged to the point that it could still shoot but not move and these would be counted as kills. "By the time the ground attack began, General Schwarzkopf had effectively abandoned any effort to base operational decisions on precise estimates of damage assessment." [100]

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[99] Cordesman, A., Wagner, A. (1996). The Lessons of Modern War Volume IV: The Gulf War. Westview Press, Boulder. P. 307

[100] Ibid, P. 308

4. The Great Scud Chase

Mobile missile launchers presented the greatest difficulty in the areas of detection and targeting during the Gulf War. Much was known about the Scud production and support facilities because of monitoring the Iran-Iraq war. However, a significant gap existed in the knowledge of how Iraq would doctrinally deploy its Scud missiles. These gaps included what types of targets Iraq would choose when facing a coalition, how it would deploy its missiles and what firing techniques it would use. There was also a gap in knowing how many launchers Iraq had in its inventory.

Intelligence analysts based their assessments of Iraqi Scuds on doctrine developed by the Former Soviet Union. Soviet doctrine dictated long deployment times with an extensive amount of time required for set up of the firing site, calibration of the missile telemetry as well as time to tear down the firing site. These procedures were required when targeting small military sites or targets as well as key facilities in urban areas. These procedures required a minimum of 40 minutes and as high as 90 minutes to accomplish all tasks. Additionally, Soviet doctrine called for fixed launch sites with centralized bases for the missiles. Instead, Iraq chose to target large urban areas, skipped many of the calibration and set up procedures and

then fired. Many of these missiles were fired from sites that had been pre-surveyed and required a minimum of set up. Using these minimal procedures, Iraq was able to develop its own *shoot and scoot* doctrine. "Iraqi Scud teams could fire a missile, drive away, and hide in a culvert, all within five minutes. Then after letting the launcher cool some more (to reduce its infrared signature), they would drive off to some remote location to wait out the day, resuming firings the next night. In Basra, Iraqi forces took to hiding Scud Transporter Erector Launchers (TELs) in residential neighborhoods as well, also hiding them under highway overpasses."[101]

Iraq also took advantage of the five and a half months leading up to Desert Shield to disperse its missiles throughout the desert, away from production and support facilities. This reduced the travel and exposure time of the missiles and prevented the concentration of its missile forces denying the coalition an easy target. The initial estimate of Iraq's Scud force was approximately 48 launchers. "Intelligence eventually concluded the Iraqis might have as many as 15 battalions with 15 launchers

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[101] Hallon, R. (1992). Storm Over Iraq: Air Power and the Gulf War. Smithsonian Institution Press, Washington D.C. p. 183

apiece-a whopping total of 225, over twelve times as many launchers as estimated on the eve of the war."[102]

The Scud missiles presented a significant threat to the coalition because of the danger that Scuds falling on Israel might bring Israel into the war and cause the predominantly Arab coalition to unravel. However, they did not present a significant threat in purely military terms. Despite their limited value militarily, the political factor placed Scuds at the top of the list for destruction. During Desert Storm, the Air Force flew 1,460 airstrikes against Iraq's Scud forces. In comparison, "the coalition flew 260 strikes against leadership targets, 580 strikes against C4 targets, 970 strikes against military industry, 1,170 strikes against Lines of Communication, 1,370 strikes against SAMs, 1,460 strikes against airfields, and 23,430 strikes against ground forces."[103]

These airstrikes were conducted by numerous types of aircraft with extremely limited results. In fact, "there is no hard evidence that the Great Scud Chase destroyed even a single Scud missile or mobile launcher."[104] Before the Gulf

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[102] Ibid, p. 179

[103] Cordesman, A., Wagner, A. (1996). The Lessons of Modern War Volume IV: The Gulf War. Westview Press, Boulder. p. 329

[104] US Congress. (August 16, 1993). Intelligence Successes and Failures in Operations Desert Shield/Storm. Washington D.C., GPO. p. 12

War started, tests and exercises aimed at destroying simulated Scuds were conducted by the US Air Force. These exercises determined that Air Force aircraft could not locate the launchers during daylight and had little success at night. Tests also determined that even if an F-15E aircrew was given a 1 by 1-mile square in which a launcher was located, this information was not accurate enough to allow the aircrew to target the launcher. These tests were conducted using Soviet doctrine in which the launcher would be stationary for 40-90 minutes as opposed to the 5-10 minutes, which actually occurred in Desert Storm.

During Desert Storm the Iraqis conducted all launches at night making detection significantly more difficult. They also timed their launches to coincide with peak periods of cloud cover to defeat satellite observation. However, the coalition did have some advantages. The soft and sandy terrain in Iraq and efforts by the Scud missile forces to avoid radio signatures caused them to travel on roads close to landlines for communications. This however, was not enough to improve detection and targeting. During the conflict, aircraft patrols observed 42 Scud launches. Of these, only eight resulted in detections that supported follow on airstrikes. There is no evidence to indicate that any of the eight airstrikes resulted in a kill. Part of the difficulty in targeting the Scuds was attributed to the use

of decoys. Iraq made extensive use of decoy missiles in and around launch areas. "Some of these decoys were so realistic that UN inspectors later stated that they could not be distinguished from real launchers on the ground, and they were mixed with low-fidelity decoys to make targeting even more difficult."[105]

Given the lack of success in detection, targeting and destruction of these missiles by the Air Force, Special Operations Forces (SOF) from the United States and Britain were given the task. These forces took the form of an 877-man force composed of special operations aviation and ground forces. These forces infiltrated primarily into western Iraq with the mission of conducting surveillance of suspected Scud missile production, support and launch sites. They were also tasked with conducting reconnaissance in the open desert to locate dispersed TELs before they had a chance to fire their Scud missiles. SOF forces were not very effective at the tactical level. However, their operations did have a strategic and political effect. Knowledge that the U.S and Britain had committed their most elite ground and air forces was a contributing factor that prevented Israel from entering the war.

[105] Cohen, E. (Ed.) Gulf War Air Power Survey, Volume II, Part II, p. 331, 334-336, 340.

5. The Ground War

The United States had a total of 50 Pioneer Unmanned Aerial Vehicles (UAVs) in its inventory at the start of Desert Storm. The Army had only one Pioneer platoon at the start of the war and it did not arrive in Saudi Arabia until late January and did not fly its first mission until February 1st. The Army pioneers flew a total of 46 sorties for a total of 155 flight hours. "The USMC had four Pioneer companies which were used for real time situation analysis utilizing day television cameras and forward-looking infrared sensors. The USMC flew 138 missions and 318 hours during Desert Shield and 185 missions and 622 hours during Desert Storm." [106] The US Navy was able to use Pioneers off two different battleships in the Gulf for 151 sorties and 520 flight hours. The Pioneer UAVs received accolades from the forces that used them. The pioneers provided near-real time imagery for tactical commanders of the targets that were directly in front of them. However their range of 120 miles and loiter time of 4-5 hours prevented their use in targeting and BDA deep into Iraq.

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[106] Ibid, p. 320

E. TECHNOLOGY

1. Satellite

Satellites, which comprise the National Technical Means (NTM) for intelligence gathering, acted as the primary source of intelligence information during Desert Shield and Desert Storm. The US had a variety of satellites available during the conflict.

a) KH-11 Imagery Satellite

Three KH-11 imagery satellites were in orbit during Desert Shield/Storm. These satellites were known by the codename KENNAN. The KH-11 "flies lengthwise with the axis of the optical system parallel to the earth. In front is a downward looking mirror that can be rotated from side to side, causing a periscope effect in which the area being viewed can change from moment to moment."[107] The primary ground station for the KH-11 satellites is the Mission Ground Site at Fort Belvoir, Virginia. Its official name is the Defense Communications Electronics Evaluation and Testing Facility.

These satellites could not image targets through cloud cover and 40-60% of Iraq was covered with clouds from December 1990 through January 1991. The fact that Kuwait was

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[107] Richelson, J. (1995). The US Intelligence Community. Boulder, Westview Press. p. 152.

covered with smoke from burning oil fields during approximately 50% of the satellite observations also reduced their effectiveness. This generation of satellites also lacked wide area coverage that caused some planners to compare them to "searching New York City by looking through a soda straw."[108]

The greatest value of the KH-11 is that it was the first satellite that could not run out of film. While previous satellites would drop a film canister from space for retrieval, the KH-11 could digitize the images it took and transmit it to a ground station in near real-time. The ability of the KH-11 to digitize imagery combined with an increase in its fuel payload greatly extended its life span beyond previous satellites. While previous satellites (KH-8 and KH-9) had a life span of 270 days, the KH-11 far surpassed their performance (Figure 4.1)

[108] US Congress. (August 16, 1993). Intelligence Successes and Failures in Operations Desert Shield/Storm. Washington D.C., GPO. p. 10

Launch Date	Deorbited	Lifetime (Days)
December 19, 1976	January 28, 1979	770
June 14, 1978	August 23, 1981	1,166
February 7, 1980	October 30, 1982	993
September 3, 1981	November 23, 1984	1,175
November 17, 1982	August 13, 1985	987
December 4, 1984	November 1994	3,625^
October 27, 1987	November 1992*	1,825^
November 6, 1988	Still in Orbit	-------

* Inferred from a late 1992 launch.
^ Approximation

Figure 4.1
KH-11 Lifetimes [109]

During the initial stages of the KH-11 program the CIA was successful in its argument that KH-11 imagery should not be provided to the military. The reasoning was that its capabilities were so advanced that to prevent its compromise only senior level policy makers should have the data. This policy held until a disgruntled CIA employee sold the KH-11 technical manual to the KGB. Various classified photos taken by the KH-11 have been published in open sources. One notable example occurred after the failed Iran Hostage rescue mission. Various photos were left behind in helicopters at Desert One. These photos were recovered by the Iranian military and published by Iranian students.

While the KH-11 has consistently proven its value, its deployment has been problematic. During the mid 1980s the US was reduced to one KH-11 satellite. The intent of the intelligence community was to maintain at least two in orbit

[109] Richelson, J. (1995). The US Intelligence Community. Boulder, Westview Press. p. 153.

at all times. On August 28, 1985, an attempt to launch a KH-11 using a Titan 34D booster failed crashing into the pacific. The destruction of the space shuttle Challenger soon after, eliminated the shuttle as a method of transport. Attempts to launch a KH-9 substitute failed when another Titan 34D booster exploded destroying the satellite at a height of 800 feet. Finally, on October 26, 1987 a Titan 34D carrying a KH-11 was successfully launched. In the meantime, the United States had to rely on one satellite for a period of over two years.

b) Lacrosse Radar Imaging Satellite

This satellite was initially known by the code name INDIGO and was later named LACROSSE. Its initial purpose was to locate Warsaw Pact armor forces during all weather conditions, especially cloud cover. This is critical as many countries are covered by clouds as much as 70% of each year. In order to develop a picture of an area or a region it might take a years worth of imagery organized as a montage to develop a complete picture. This satellite provided thousands of images during Desert Shield/Storm. It effectiveness was reduced as it only passed over Iraq twice daily and could not discriminate between different types of vehicles. Processing of data required on average 15-20 minutes for downlink and processing. It assisted in

targeting and bomb damage assessment (BDA). However, BDA of tanks was accomplished by looking for vehicles that remained stationary after an air strike. If the vehicle did not move for a lengthy period, the photo analysts assumed that the vehicle had been destroyed.

The LACROSSE satellite orbits at about 400 miles above earth and has a resolution of approximately 1-meter. In comparison, the KH-11 has a resolution of approximately 10 centimeters. While the LACROSSE can image through clouds, its limited resolution prevented it from detecting details such as scorch marks on a target which would indicate the destruction of a vehicle or building. Data from the satellite is relayed to a ground station in White Sands, New Mexico by a Tracking and Data Relay Satellite.[110] Martin Marietta built the satellite at a cost of approximately 1 billion dollars.

c) The Defense Support Program Satellite

The DSPS uses a twelve-foot infrared telescope to detect the infrared plumes of SCUD missile launches. The DSPS satellites had been used to track Iraqi SCUD testing in December of 1990. These satellites had the capability to transmit and share data in real time with JSTARS, Patriot

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110 Richelson, J. (1995). The US Intelligence Community. Boulder, Westview Press. p. 157.

missile batteries and other systems. The accuracy of the DSPS was limited to determining the location of a launch within 30 nautical miles and the data would take several minutes to process. The DSP could not locate the SCUD launchers with enough accuracy for follow on air strikes.

2. Air Surveillance

Air Surveillance was used in conjunction with satellites for the detection, targeting and bomb damage assessment of tactical targets. While satellites were used during both Desert Shield and Storm, these systems were not used until the start of the air war.

a) JSTARS

The Air Force-Army Joint Surveillance and Target Attack Radar System (JSTARS-E8A) was still in development at the onset of Desert Shield/Storm. It was an airborne surveillance aircraft similar to the AWACS but designed to focus on ground targets instead of aircraft. It consisted of a modified B-707 aircraft with a variety of computers, sensors, and communications systems that allowed it to transmit data to ground station modules. These modules could be deployed in theater as well as the United States. It provided commanders with near real time information on moving targets in virtually all weather conditions.

The JSTARS is equipped with Side-Looking Aperture Radar (SLAR) with a high resolution. It is mounted in a 24-foot radome in the nose of the aircraft. "It typically operates at a distance of 80-120 kilometers from the front lines and can detect vehicle locations, numbers and movement."[111] Surveillance coverage of areas measuring 25 by 20-kilometer sections can achieve great detail and detailed targeting can be achieved using 4 by 4-kilometer sectors. The US Air Force (USAF) initially resisted the deployment of JSTARs to the Gulf because it was an experimental system. The USAF believed that it might complicate the conduct of air battle management and there was also the danger that it might be lost to air or ground fire. This resistance continued even though the USAF knew that December through February were the worst months for satellite imagery due to heavy cloud cover. Clouds could be expected to obscure the region from 40-60% of the time. This system was eventually deployed to the Gulf because of congressional inquiries combined with requests from 7th Corps officers, had seen a successful demonstration of its capabilities.

Two JSTARs were deployed to the Gulf and arrived a few days prior to the start of Desert Storm. Both were experimental and were deployed missing large components that

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[111] Cordesman, A., Wagner, A. (1996). The Lessons of Modern War, Volume IV: The Gulf War. Westview Press, Boulder. p. 286

had not yet been completed. The JSTARS lacked the ability to discriminate between vehicle types and it could not detect stationary vehicles. It's computers also proved inadequate to handle all of the data processing requirements of its systems. This created numerous difficulties when communicating with strike aircraft for battle management. The JSTARS systems also required extensive maintenance. The lack of spare systems and parts required the cannibalization of one aircraft to keep the other flying. This limited the degree of coverage possible and resulted in a total of 44 air missions during the entire war. The ground station modules also had problems. They were initially designed to handle the data from the JSTARS and other surveillance aircraft simultaneously. However, it quickly became apparent that the modules could only handle data from one aircraft at a time.

b) TR-1

The TR-1 is the successor to the U-2R surveillance aircraft. Its purpose is tactical reconnaissance. It has a high-altitude reconnaissance capability with speeds in excess of 430 miles per hour and a range of 3,000 miles. The TR-1 can fly at altitudes in excess of 70,000 feet. It was equipped with an electronic intelligence capability, advanced synthetic aperture side-looking radar (ASARS),

photographic and infrared capabilities. These capabilities enabled the TR-1 to cover an area 180 kilometers wide and 5,000 kilometers long on a single mission. The ASARS was regarded as an excellent system for detecting moving targets and battle management. The TR-1 was deployed with a mobile ground station, which could receive and process the radar data in real time and disseminate it to the user level. However, the TR-1 is susceptible to anti-aircraft defenses and requires a "force package" of electronic jamming aircraft and fighters to defend it. Five TR-1 aircraft were deployed to the Gulf.

c) U-2R

The U-2R is a strategic surveillance aircraft. The U-2R has a wingspan of 103 feet, a height of 16 feet and a length of 63 feet. It can range 3,000 miles with a maximum speed of 528 knots at an altitude of 40,000-70,000 feet. It was a successor to the U-2 series of aircraft. The U2-R is equipped with an H camera system, which can provide resolution varying from 6 to 18 inches at a distance of 35-40 nautical miles. It is also equipped with an advanced synthetic Aperture Radar System (ASARS) which is an all-weather and light condition imaging system. It was designed to detect, locate and classify ground targets. The ASARS is designed to provide 10-foot resolution in near real time. It

is also capable of slant photography in which it can look into a target area at an angle without having to cross a border or into an area defended by anti aircraft systems.

d) RF-4C Phantom II

The RF-4C is a multi-sensor reconnaissance aircraft capable of day and night operations. It can fly at altitudes of 100 to 45,000 feet at speeds in excess of 600 miles per hour. It has optical, infrared and electronic reconnaissance systems. Its cameras have good resolution for high and low altitude photography during the day. It also has an infrared sensor that can produce a continuous map at night of the area located along the aircraft's flight path. It can record reconnaissance data on film but this must be downloaded and processed after landing. This feature prevented BDA and targeting data from being used in real-time. A total of 24 RF-4C aircraft were deployed to the gulf, 12 of which did not arrive until just before the air war began. "It took outside command pressure on the Air Force to persuade it to devote ramp space to the RF-4Cs."[112] At the time of Desert Storm, the RF-4C aircraft were considered by many to be obsolete. They had initially served as reconnaissance aircraft in Vietnam and only a small number of the aircraft remained in the inventory, almost all

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[112] Ibid, p. 312

of which were in the air national guard. The RF-4C flew 822 sorties largely in support of BDA missions.

e) UAVs

Each of the services had an Unmanned Aerial Vehicle (UAV) program at the time of the Gulf War. The Army had previously canceled its Acquilla UAV program because of program mismanagement. The US Air Force was in a similar situation as it had concentrated on developing strategic UAVs which had little application for tactical and theater operations. All of the services were forced to rely on a modified Israeli UAV named the Pioneer until others could be developed.

(1) Pioneer. The Pioneer unmanned aerial vehicle has a length of 14 feet and a wingspan of 17 feet. Its range was approximately 120 miles and it has a mission altitude of 1,000 to 12,000 feet. The Pioneer's most significant limitation is that it is a line of sight aircraft. The Pioneer must operate within line of sight (avoid terrain which might interrupt its command frequency) of its associated ground station. It has an endurance of 4-5 hours, and has both video and a forward-looking infrared capability. During UAV operations 12 were destroyed, 11 suffered major damage and 3 suffered minor damage. Out of these, 1 was shot down by ground fire, 2 destroyed by

operator error, 3 by electro-magnetic interference and 6 from general or engine failure. Damage was due to small arms fire, operator error and engine problems.

While the pioneer UAV system was relatively primitive at the time of Desert Storm, it was successful because it was able to support the needs of the tactical commanders. UAVs provided focused, real-time information on what was in front of the divisions and corps. It was a survivable system, as the loss of a UAV did not mean the loss of an aircrew. It could loiter over a target area for a few hours while providing target observation from different angles. The Pioneer could provide the resolution needed to detect tanks, convoys, and troop movements during daylight that were needed at the tactical level. However, the Pioneer lacked the range needed for targeting and BDA of targets deep inside Iraq and Kuwait.

(2) Pointer. The pointer was a light, hand-launched remotely piloted vehicle used by the Marine Corps. It was a failure as it was very fragile, and had an extremely limited range that prevented it from gathering enough information over a widely spread battlefield to be useful.

(3) High Altitude Endurance UAV. With the cancellation of the SR-71 theater reconnaissance aircraft, the US Air Force planned a long-loiter, high-altitude, unmanned aerial vehicle as its replacement. This program was a failure with technological problems at numerous levels resulting in crashes. The cancellation of the SR-71 combined with a failing follow on program left the US Air Force without a theater reconnaissance aircraft during the Gulf War. Attempts were made to revive the SR-71 during and after the war but the costs and lack of aircraft parts prevented its return. The High Altitude Endurance UAV never flew during the war.

E. ANALYSIS

In the aftermath of the Gulf War Brigadier General Scales [Army Chief of Staff for CENTCOM]wrote that "Strategic intelligence, intended to support a host of users at the national level, has only limited application to tactical theaters. In the desert, commanders' expectations, especially below corps, remained unmet. Finished intelligence produced at the national level was not necessarily suitable for tactical planning."[113] While many were unsatisfied with the amount of intelligence available, Desert Storm was probably the most successful war the United

[113] Scales, R. (1994). Certain Victory: The US Army in the Gulf War. Washington D.C., Brasseys. P. 163-164

States has fought. The US military accomplished its objectives rapidly with the added benefit of minimal casualties. However, there were many lessons to be learned, especially at the tactical level. One of these lessons is the need for improvement in order to achieve *precision engagement*.

As noted, Precision Engagement has five component parts: Targeting, Command and Control (C2), the ability to achieve a desired effect, the ability to assess the level of effectiveness achieved (BDA) and the ability to re-engage when required. In order to achieve these requirements the air and space sensors had to fulfill a number of criteria. (See Figure 4.2.)

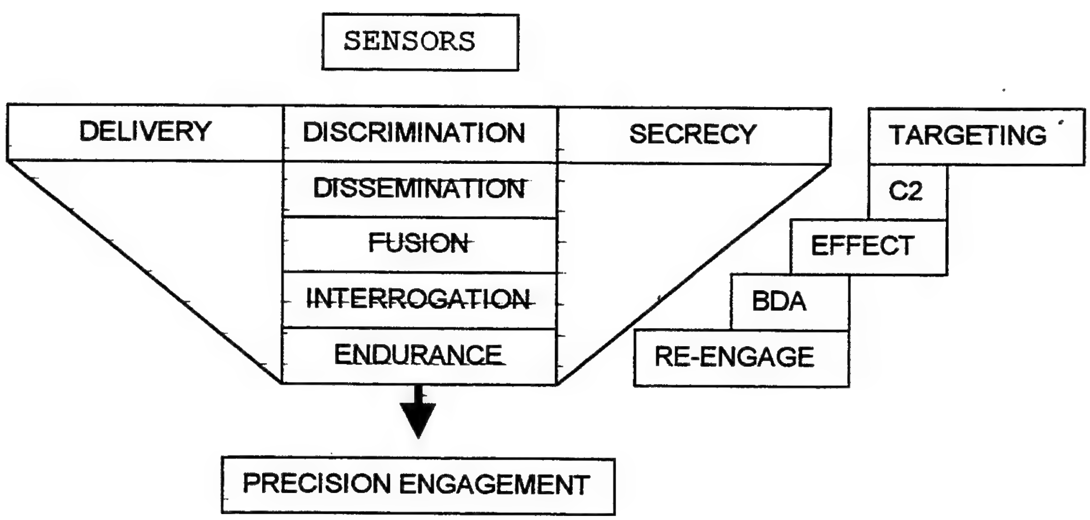

Figure 4.2.Sensor Criteria for Precision Engagement

1. Targeting

For targeting, sensors had to be delivered to a

location or orbit where they could sense the target. Second, the sensors had to be covert to prevent the enemy from destroying them or innovating around them. Third, the sensors had to be capable of discriminating between a variety of targets.

a) Delivery

Satellites were the dominant form of surveillance during the Gulf War. The United States was fortunate that it had a great number of imaging satellites in orbit at the beginning of Desert Shield. In fact, the four imaging satellites available constituted a larger number than had previously been in space at one time. While these satellites were already in place, their historical deployment has been problematic. Satellites are extremely expensive to build and have a finite life span. Putting them in orbit is another problem. While numerous satellites have been built, many are waiting in storage for a means of delivery into orbit. Just prior to the Gulf conflict, the United States found itself with only one imagery satellite in orbit due to launch failures and the destruction of the Space Shuttle Challenger. Satellites cannot be launched on short notice due to the extensive logistical requirements, cost and limited number of delivery systems. Additionally, the short duration of many contingency operations conducted by the

military would result in satellites being deployed at the tail end of conflicts or after the fact. While there were an extensive number of satellites in orbit during the Gulf War, that number has been significantly reduced in recent years due to declining budgets. It is doubtful that if the Gulf War were conducted today that space systems would play as important a role in the conflict.

The ability to deploy aircraft sensors within range of the enemy was a mixed story. The JSTARS and TR-1/U2-R aircraft had to conduct surveillance of the enemy from a standoff distance due to the Iraqi air defenses. The U-2 series aircraft has a history of being shot down over denied territory with multiple losses in Russia and China. The loss of an aircraft not only results in the loss of an aircrew and sensor system but may also provide the enemy with access to technology that he might not otherwise have. While these aircraft could sense targets from a standoff position, they did not have the range to provide coverage of the entire battlefield. This required international agreements with Syria and other countries for permission to overfly their territory. Other nations may not be so willing to provide this access in future conflicts.

Unmanned Aerial Vehicles were widely praised during the Gulf War. They could be launched from the front providing reconnaissance for the lead Corps and Divisions.

The UAVs were survivable, as their loss did not equate to the loss of an aircrew. Additionally, the UAVs were basic enough that the loss of UAV technology would not compromise a secret technology. However, the range of the Pioneer UAV was limited to 120 miles preventing its use in the deep battle area in Iraq and Kuwait.

b) Covert

None of the satellites were covert. Iraq had accurate information regarding the orbits and observation times of the satellites as well as a general knowledge of their capabilities. Russia and other countries provided much of this information. Iraq also purchased a large amount of satellite imagery from commercial companies and foreign sources which enabled it to determine how to innovate around the satellites. This led to the use of decoys, which were detected as if they were the real thing. It also led to tactics of dispersion, rapid launches, and operations at night during periods of maximum cloud cover. Iraq even started hundreds of oil fires throughout Kuwait to create a smoke screen to defeat coalition surveillance systems.

The sensors of the JSTARS and TR-1/U2-R were not covert. The aircraft could easily be detected by radar requiring that they operate at a standoff distance. While the aircraft could defy the radars if accompanied by

electronic jamming aircraft, this required a force package of aircraft to support the operation. By the very nature of jamming the radars, the aircraft would be signaling that they were in the area. The Iraqi innovations of launching Scud missiles during cloud cover or under the umbrella of smoke also inhibited the surveillance aircraft.

c) Discrimination

Satellites had a variety of capabilities for discriminating between targets. The KH-11s could discriminate between tanks, armored personnel carriers and other types of vehicular targets. However, they did not have the resolution necessary to detect personnel. Air surveillance aircraft could detect moving targets such as cars or tanks but could not differentiate between them. As such a convoy of cars would look the same as a convoy of tanks. Additionally, these aircraft could not detect stationary targets. While much has been said of Iraq's failure to act offensively, its defensive tactics frustrated the detection efforts of air surveillance. UAVs were successful in discriminating between different types of targets ranging from tanks to infantry soldiers. However, the utility of UAVs was limited by their short range, limited loiter time and reliance on line-of-sight communications.

2. Command and Control

Command and Control is the ability to manage a diverse amount of forces and resources to accomplish a particular mission. In the Gulf War, commanders had to manage a large amount of information such as imagery, and send it to the right user to increase their chances of mission success. Central to successful Command and Control in the Gulf War was the ability to disseminate information about the enemy.

a) Dissemination

Processing and the dissemination of satellite imagery was one of the major bottlenecks during the conflict. While a number of secondary imagery systems were available, each of the military services and other joint commands had different systems. These did not share a standardized communications protocol and were not interoperable. While some systems proved their value, they arrived in theater late in the conflict, they were very expensive and they were limited in number. While data could be passed in near-real time, the security classification of the material prevented its transmittal over anything but a secure fax machine. The lack of adequate Secondary Imagery Dissemination systems (SIDs) resulted in the use of couriers adding as much as 18 hours or more to the time required for dissemination. Dissemination was also limited as the

secretive nature of US satellite capabilities often limited the ability of the military to share the photos with forces at the lower echelons.

Air surveillance aircraft performed significantly better than their satellite counterparts. Both the JSTARS and TR-1 aircraft could transmit their images and surveillance data in real time to other aircraft and ground stations. This supported the rapid dissemination of targeting data to other aircraft in flight. However, the ground stations often became the bottleneck. Ground systems that were supposed to simultaneously handle the information provided by multiple aircraft became overloaded. This overload reached the point where each ground station could only support one aircraft. Some aircraft were limited to film based reconnaissance which required development in theater after the aircraft landed.

Unmanned Aerial Vehicles also performed dissemination well. UAVs could transmit optical imagery in real time to their associated ground stations in theater. This enabled the lead Corps and Division commanders to visualize the battlefield immediately in front of them. However, the ability to share the data was limited by the number of ground stations. The limited size of the UAV force (The US Army had one platoon in the theater) limited their success.

3. Effect

The ability to achieve a desired effect against a target is not restricted to the sensor itself. It encompasses accurate targeting, the size and type of force allocated to the mission and the type and quantity of munitions expended against a target. In order to facilitate these requirements, various types of sensor data must be fused together to provide a complete picture of the target and the battlefield.

a) Fusion

Satellite and air surveillance data were not fused into a coherent picture of the battlefield. Each type of data was treated in a separate manner with a priority focus on optical imagery. While multiple types of sensings could be made, each target would often be detected, attacked, and assessed for BDA based on a single image. This image was often an optical image taken during daylight and after the third day of the air war, optical images were often late, inaccurate or unusable. The inability to fuse the data was partly a result of poor dissemination. However, a larger part of the story was the inability of the ground stations to process data from more than one aircraft at a time or the lack of ground station terminals in theater. Yet another aspect was the centralized control held over these systems

in which processing was conducted in the United States and then forwarded into theater.

4. Battle Damage Assessment

BDA is the ability to assess the level of effectiveness of an airstrike or attack by determining if a bomb or munition had hit its target, and if hit what effect that had achieved. Various methods have been employed to assess battle damage. The ultimate goal is to get the target to tell you if it is alive or dead. This is done by observing its actions or signature relative to a functioning target or previous observation of the same target. This is best described as interrogating the target.

a) Interrogation

The Gulf War is another in a succession of historical failures to adequately conduct bomb damage assessment. While much has been written of the failure to adequately conduct BDA in the Gulf, the United States has historically had immense problems in this area. This failure was more of an inability to learn and prepare based on lessons from previous conflicts as opposed to a unique problem that occurred in the Gulf. Bomb damage assessment in general is a lengthy and highly inaccurate process. Multiple types of methods were used to determine if a weapon had hit a given target and if hit, whether it had achieved a kill.

The coalition forces were more successful at determining if a bomb hit its target.

Many observers were awed by the use of precision guided munitions during the Gulf War. Videotapes of bombs penetrating a precise location such as a window or ventilation duct were shown on TV. However, the military was unable to determine what level of destruction had been achieved as the effects of the bombs were often contained within the building. Even more problematic was the ability to assess the effect achieved on dispersed targets such as tanks. This required thousands of images to determine if area munitions had destroyed individual tanks. While scorch marks, were sometimes a telling sign of the destruction of a building, evidence to indicate the destruction of a dug in tank was much more obscure. This forced the coalition to assess the destruction of a tank largely on whether or not it was moving or stationary. If it could move it was alive, if it was stationary, it was dead. Iraq's reliance on stationary and defensive tactics prevented an accurate accounting of its forces.

What the coalition needed was the ability to interrogate the target to determine if it was alive. Were soldiers located around the vehicle? Was the engine of the tank emitting exhaust fumes? Was the tank making noises that could be detected by an acoustic sensor? Despite the desire

to remain concealed, the crews of these types of vehicles had no choice but to run their engines periodically to recharge their batteries. Without charged batteries they could not start their vehicles, power their sights, enable radio communications or operate heaters. These are the kinds of emissions that would have indicated the life or death of a tank. These were exact types of signals that air and space surveillance could not detect.

This inability to conduct BDA led to repeated airstrikes against the same tanks or target until the damage was so catastrophic that it was obviously dead. This placed numerous aircrews in harms way as they attacked through heavy air defenses and placed their lives on the line to attack a target that had been *killed* two or three times before. It also resulted in the excess expenditure of different types of munitions to conduct repeated airstrikes.

5. Re-engage

After assessing the effect of munitions against a target, assessors invariably conclude that some have escaped destruction or have sustained minimal damage, which allows them to continue operating. This necessitates the ability to reengage a target when required. Central to this requirement is the endurance of a particular sensor. If it can operate 24 hours a day every day, then it can support targeting,

command and control, and BDA for a second strike against the same target.

a) Endurance

The satellites and reconnaissance aircraft were not capable of providing 24-hour coverage of the battlefield. For satellites, this was a function of their orbit that would result in one pass every five or twelve-hours. Each of these passes would often be of different locations of Iraq and Kuwait. Satellites were also inhibited by the limitations of their onboard sensors. The inability to observe the battlefield at night, through cloud cover, or through a man-made smoke screen prevented 24 hour a day coverage of the battlefield.

Surveillance aircraft were not capable of filling the gap. Their fuel capacity and aircrews limited their endurance. There were only two JSTARS aircraft available and one was constantly being cannibalized in order to keep the other flying. Aircraft flying in a protecting role for electronic jamming and fighter escort had even less endurance than the aircraft conducting the surveillance. Finally, aircraft such as the RF-4C were limited to film based surveillance and the only way to obtain the reconnaissance information required them to return to base for developing and analysis of their film. This limitation

inhibited 24 hour targeting, command and control, the ability to achieve a desired effect, the ability to assess the destruction of targets, and the ability to re-engage targets that were not destroyed after an initial airstrike.

V. RESEARCH QUESTIONS

That's an amazing invention, but who would ever want to use one of them?

-President Rutherford B. Hayes[114]

A. INTRODUCTION

The purpose of this chapter is to answer two research questions.

- What role can UGS fill in precision engagement?
- What are the costs, benefits, and unintended consequences of UGS?

The answers to these questions will be used to generate a prescription for the future of UGS while demonstrating its linkage to historical evidence. This chapter will conclude by summarizing the results of the study

B. ROLES AND MISSIONS

There are two roles which ground sensors can fill in *precision engagement*. First, UGS may substitute for other systems. This could achieve an economy of force enabling a high-cost or limited air or space sensor to focus on other missions. UGS may also be used as a substitute for highly classified sensors enabling sensor information and

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[114] Comment made by President Rutheford B. Hayes to Alexander Graham Bell upon the invention of the telephone. Malone, J. (1997). Predicting the Future: From Jules Verne to Bill Gates. New York, M. Evans and Company, Inc.

technology to be shared with a coalition partner. A second role for UGS is as a complement to other systems. UGS would be used to provide a capability air and space sensors cannot or as a force multiplier to augment other sensors. This would support specialized missions requiring specific intelligence, an ability to speed detection and targeting, or to enable force projection of a tactical military intelligence capability.

1. Substitute Role

a) Release of Air and Space Assets

UGS have the potential to substitute for high-cost and limited resources. This would release aerial reconnaissance aircraft and satellites from a tactical role and enable them to focus on strategic priorities. Both the peacekeeping mission in the Sinai and the conduct of operation *Igloo White* in Vietnam are examples of using ground sensors as a "substitute." In these cases, UGS provided an expansion of choice for targeting and *precision engagement*. UGS also provided a capability that air and space sensors could not. Air and space sensors did not have the endurance, or resolution necessary to target individual soldiers and vehicles in either the Sinai or Vietnam. They were also limited in their ability to target an enemy hiding

under triple canopy jungle.[115] Use of UGS as a substitute may also extend the life span of other sensor systems such as satellites because they would not be required to perform as many missions or be re-tasked which might reduce their limited fuel supply.

b) Coalition Support

The US led coalition in the Gulf War was almost completely dependent upon US intelligence gathering capabilities. The great disparity between the American and Iraqi intelligence capabilities placed the coalition in a position of fighting a "blind" enemy. However, if the U.S had not been part of the coalition it is believed that the conflict would have been characterized as the *blind fighting the blind*. While the US did share a great deal of intelligence information with its coalition partners, it was a very difficult process in which certain materials could not be shared due to the sensitive nature of their collection. It was also difficult because the coalition forces did not have the technology to receive or disseminate imagery and other types of intelligence. UGS hold the potential of acting as a substitute for much of the

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[115] See Callan, C. (1996). Microsurveillance of the Urban Battlefield. McLean, Virginia, Mitre Corporation.
Also see Cindrich, I., Del Grande, N., Johnson, P. (1993). Underground and Obscured Object Imaging and Detection. Washington, SPIE

classified intelligence and targeting systems used in the gulf. The development of unclassified sensors and monitoring equipment could be shared with coalition partners during a conflict. Unclassified UGS could also be provided to a non-US led coalition to enable them to conduct targeting without requiring constant support from US intelligence sources.

While some may become concerned that UGS might be used in a manner contrary to US interests, this danger can be reduced. A solution might be the use of "expireware". Either the sensors, monitoring equipment or both could be loaded with software that has a built in expiration date by either date or number of uses. Or, it could be loaded with a device that requires it to receive a periodic signal, which allows it to continue operating.

2. Complementary Role

a) Specialized mission

UGS may be used to complement other sensors to accomplish a specialized mission. The Son Tay rescue mission in North Vietnam is an example. During the Vietnam War, intelligence information gained by satellite photography indicated that a number of American pilots were being held as prisoners of war (POW) in a North Vietnamese Prison camp called Son Tay. Their initial presence was confirmed through air and space photography of code letters marked on the

ground by the POWs. A rescue force was assembled and trained for the mission. In the weeks leading up to the mission, concerns arose as to whether the POWs had been moved. An agent was infiltrated into North Vietnam to reconnoiter the outside of the camp but was unable to confirm the presence of American POWs. The operation was later conducted and was unsuccessful in rescuing POWs as they had been relocated a short time earlier. After the mission failed, "Military Intelligence officials would admit that there was one *ace card* they had failed to play: acoustic and seismic sensors to *spike* the camp at Son Tay." [116] Brigadier General Donald Blackburn the commander of the Son Tay mission had even been part of the development of the sensors but had not thought of using them for the mission. "In retrospect [Blackburn] said he would have spiked the camp, and to mask the real objective, the Air Force could have seeded every other rice paddy in North Vietnam." [117]

b) Force Multiplier

The great Scud chase is an example of how UGS could be employed with great benefit as a complement to air and space sensors. In the Gulf, satellites and air surveillance were successful in locating fixed launch pads

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[116] Schemmer, B. (1976). The Raid. New York, Avon Books. p 101

[117] Ibid, p 103

for Scuds as well as factories and other fixed facilities. However, in the conduct of locating mobile missile launchers, air and space systems were inadequate. Air and space sensors typically detect and provide the location of a target with the accuracy of a 1 by 1 kilometer grid square. Desert Storm proved that this level of accuracy was not sufficient. Air Force aircraft could not locate the Scud missiles and dropping a cluster bomb within this grid square did not have a destructive radius capable of destroying the target (See Figure 4.1). [118]

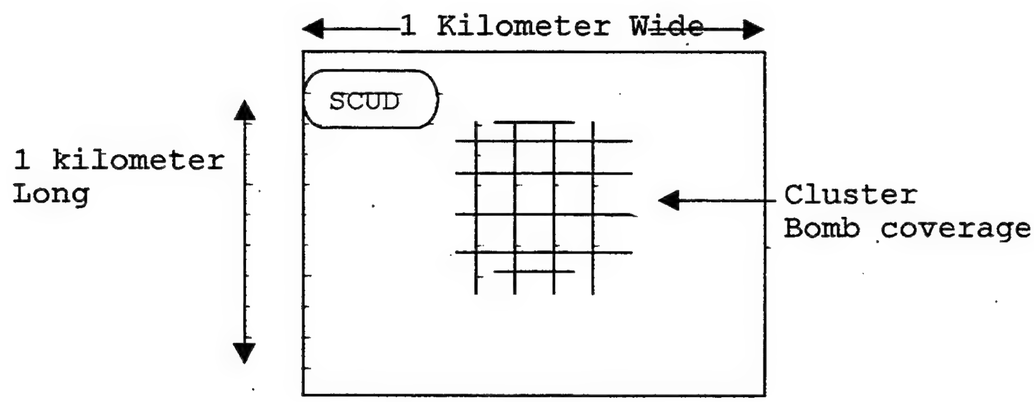

Figure 4.1
Example of cluster bomb kill radius overlaid
on satellite determined Scud location

UGS used in Vietnam were limited in their range and could only locate a target if it passed within a few hundred meters of the sensor. This limitation actually enforced

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[118] It is important to note that different types of cluster bomb munitions have a different destructive radius and capability. The coverage achieved by a cluster bomb is determined by the height at which the bomb releases its payload. Many cluster bomb munitions can achieve a very large area of coverage by releasing their payload at a high altitude but this reduces the ratio of bomblets to square feet reducing the possibility of hitting a target.

accuracy in targeting and achieved *precision engagement*. When a UGS detected a target, it meant that the target had to be located within approximately 300M of the sensor. If an Air Force aircraft dropped a bomb directly center of mass of the sensor, the kill radius of the cluster bomb was often sufficient to achieve a kill or at the very least incremental damage (See Figure 4.2). The employment of UGS in this role would serve as a force multiplier for detection and targeting where satellites and air surveillance focused on fixed launch sites, while UGS targeted mobile launchers. UGS would also provide a form of redundancy where the loss of a satellite or surveillance aircraft would not result in the inability to conduct targeting and precision engagement.

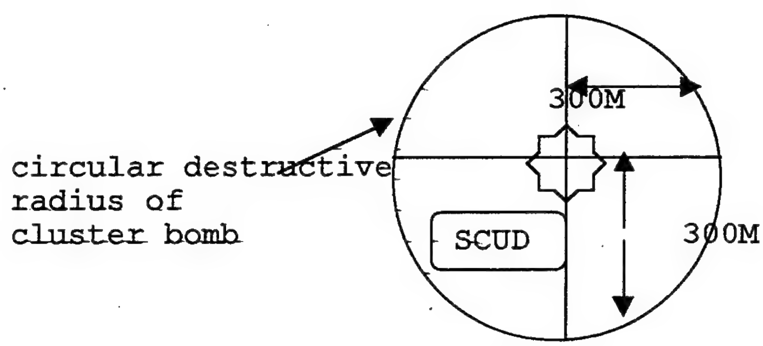

Figure 4.2
Example of cluster bomb kill radius overlaid on UGS determined Scud location

c) Force Projection

A final role for UGS is force projection. In the Gulf War, General Schwarzkopf initially left his tactical military intelligence assets behind in order to deploy

combat forces into theater. This forced him to rely heavily on National Technical Means (NTM) for targeting the Iraqi military. Part of the reasoning for this was the danger that lightly armed Military Intelligence forces would be overrun. This decision was also made with the recognition that many of the tactical collection systems available could not keep pace with a rapidly moving mechanized and armored force. The use of UGS may solve this problem. UGS have the potential of providing the tactical commander with a means of conducting targeting while requiring the deployment of a small Military Intelligence force into theater.[119] The force would consist of aircraft and special operations forces (SOF) that could deliver ground sensors. The Military Intelligence force required to monitor these sensors would be relatively small and the UGS would provide a tactical capability that was sorely lacking during the Gulf War.

C. BENEFITS AND COSTS

Unattended Ground Sensors have numerous benefits, many of which are embedded in their role as a substitute or as a complement to other systems. However, the use of UGS to reduce the "fog of war" may enable even greater benefits to

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[119] See Seffers, G. (1997, September, 1). Report: Adequate Land Mine Replacement Could Run Billions. The Army Times, p 1-4. Also see Seffers, G. (1998, January, 12). Army to Test High-Tech Battlefield Weapons: Equipment Could Boost Early-Entry Force Defenses. The Army Times, p 8.

be achieved. These benefits are "tailor to task" forces and reduced basing requirements.

1. Benefits

a) "Tailor to Task" Forces

The US military has traditionally deployed the bulk of its forces into theater whenever drawn into a conflict. This has taken excessive amounts of resources, material, and manpower to accomplish. This is done because the military wants to ensure that is has an adequate amount of forces and resources necessary to prosecute the conflict and achieve a quick solution. The need for large forces is tied to the commander's lack of intelligence information to confirm locations, strength, disposition, and capabilities of the enemy in theater. The direct result is that commanders over-estimate their needs to ensure success. Ground sensors have the potential of improving the ability of commanders to reduce the "fog of war" enabling them to accurately tailor their forces based on an accurate picture of the enemy. This "tailor to task" capability will then allow commanders to respond to conflicts faster, with smaller, more lethal forces. [120]

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[120] Schoomaker, P. (1998). Special Operations Forces: The Way Ahead. Florida, USSOCOM, p3.

b) Reduced Basing Requirements

One of the most significant issues today is the unwillingness of countries to support the forward basing of US military troops. The absence of forward bases requires the US military to concentrate on force projection, in order to remain relevant for major regional conflicts (MRC). If ground sensors significantly increase the ability to "tailor to task" forces then it should hold true that fewer forces are required to support an MRC. If fewer forces are required, then the US military needs smaller or fewer bases. As the development and employment of ground sensors and other sensor systems produces a capability that will identify the "Achilles Heel" of an enemy, the force required may be so small that a "tailored" military unit can bypass the need for a forward base and strike its target directly.

2. Costs

a) Delivery

The greatest cost of UGS is not defined by monetary concerns. It is measured by casualties and mission compromise. UGS can be delivered by airdrop or emplaced by soldiers. Airdrop requires overflight of enemy territory. Emplacement by soldiers also may involve overflights and will certainly involve placing troops on the ground. In the

Gulf War case study, both of these options would have been prohibited by General Schwarzkopf out of concern that this might cause Iraq to invade. It also invites the possibility that the delivery force might suffer casualties. In response, various government laboratories have begun to develop other means of delivering sensors. Sandia Labs, Lawrence Livermore and others are developing UAV, artillery and cruise missile delivery systems for ground sensors. [121] While these methods eliminate the danger of casualties, they are lacking on two points. First, UAVs and artillery will be able to deliver UGS at a very limited range and this will negate their value when fighting in the deep battle area. Second, while cruise missiles overcome this problem, the cost of cruise missiles is so prohibitive that they will elevate UGS into the same category as air and space surveillance with little value added. This is because each cruise missile will have a relatively small sensor payload relative to its cost.

While artillery and UAV delivery will be an effective means of supporting general-purpose forces in the

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[121] See Bendowski, M., McFeaters, R., Taylor, R. (1997). Demonstrated Delivery/Employment Systems for Unattended Ground Sensors. In G. Yonas (Ed.), Peace and Wartime Applications and Technical Issues for Unattended Ground Sensors. Proceedings of SPIE Vol. 3081, 178-186. Also see Eaton, W., Fischer, J., Kraft, G., Lafond, G., Schatmann, L. (1997). Tomahawk Cruise Missile Internetted Unattended Ground Sensor Delivery. In G. Yonas (Ed.), Peace and Wartime Applications and Technical Issues for Unattended Ground Sensors. Proceedings of SPIE Vol. 3081, 219-227.

close battle, the deep battle will most likely depend on the use of Special Operations Forces (SOF) for delivery. Special Operations Forces typically operate in the deep battle area for reconnaissance and other missions. Delivery of sensors could be accomplished as part of a mission in which sensor delivery is the primary purpose or as a secondary mission while travelling enroute to an objective. This delivery could be accomplished either in an air or ground delivery mode or both. The cost of using SOF to deliver UGS is the willingness to risk compromise and casualties during delivery.

b) Research and Development

The doctrine of the US military is based on the ability to project forces on short notice. It is also based on the notion that future wars and contingency operations will be conducted with *forces in being*. While the Gulf war was an anomaly in which Saddam engaged in "sitzkrieg" while the US led coalition deployed and trained, it is not likely that a future adversary will make the same mistake. Ground sensors must be developed, and tested now, or the military risks not being able to produce adequate UGS in time for the next conflict. While many scientists and military professionals are quick to talk of using commercial-off-the-shelf technology (COTS) as a way of speeding up the R&D

process, Vietnam demonstrates that this may not be sufficient. The Defense Communications Planning Group is an example of an organization that built its operational plan on COTS and modifying existing technologies only to spend years in the R&D process.

D. UNINTENDED CONSEQUENCES

Unintended consequences of information technologies are a very real danger. When you recognize that military technologies act as a "systems of systems," it is fair to surmise that a change in one can lead to significant changes in another.[122] These changes spawn side effects, which are unintended.[123] Some are positive if captured and addressed as part of innovation. Other side effects can have catastrophic effects if not identified until employed in war. To mitigate these effects, it is best to incorporate new technologies into the military during times of peace. This gives the advantage of time in which simulations and exercises may be conducted to develop a sound understanding of the technology, and the required tactical, strategic and organizational innovations required to exploit it. Some of

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[122] Department of Defense (1997). Joint Vision 2010. Washington D.C., GPO. p. 21.

[123] Alberts, D. (1996). The Unintended Consequences of Information Age Technologies. Washington D.C., National Defense University.

the unintended consequences, which have already been identified and other which may emerge are addressed below.

1. Precision Munitions

One of the main selling features of precision engagement is the notion that a small, lethal projectile can be fired at a target with maximum precision. This will enable forces to accurately engage and destroy military targets with minimum collateral destruction or loss of life to a civilian populace. However, Harvey Brooks in a study at Harvard University points out that "historically, greater accuracy has always brought with it an increased rate of delivery-doubling every eight to ten years by the Pentagon's own accounting."[124] Despite this constant increase in the ability to deliver accurate fire, the damage and destruction of civilian property and loss of life to civilians has constantly increased. While precision engagement holds the promise of greater accuracy, history indicates that a concsious effort will have to be made to prevent an increase in the destructive power of future weapons.

2. Technological My Lai

Part of the US Army's goal of *precision engagement* is the ability to couple sensors directly to weapons systems. This is commonly referred to as the "sensor to shooter

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[124] Dickson, p. (1976). The Electronic Battlefield. London, Indiana University Press. p. 205.

problem". The difficulty has centered on different operating systems, and technology. The idea is that eventually, warfare will be conducted in the absence of input or interaction with a human operator. Technologies such as unattended ground sensors can identify a soldier through magnetic sensors. The magnetic sensor detects the metal in a soldiers weapon and reports it as a combatant. However, the same sensor will also report "combatant" if an old man carrying a metal shovel to his farm passes by the sensor. If a sensor was linked directly to a weapon system, this could result in atrocities that could easily and regularly rival My Lai.

3. "Privates' War"

As the US military experiments with the use of simulations as part of its "Army after Next" gaming process, personnel and organizational issues have come to the forefront. In October of 1997, a simulation was conducted at Fort Sill Oklahoma involving artillery, sensors and missile systems against Scud launchers. The objective was to conduct remote warfare by connecting a variety of command centers, which had the capability of directing strikes into the deep battle area. The result was that "you've got instances where soldiers process that data in a matter of seconds-from acquiring the target to shooting-and no one above the rank

of sergeant will actually look at that." [125] During the simulation some of the most advanced, high cost and destructive weapons were fired faster than officers or senior NCOs could track. The result is that the war rapidly fell to the control of the lowest ranking members of the centers. This raises serious concerns about how best to organize as well as how we train our enlisted force.

4. Information Overload

Attempts have been made at the National Training Center to digitize an army division to test the effect of incorporating information technologies into warfare. It was widely believed that by providing commanders at all levels with a "perfect picture" of the battlefield, that the speed of the attack would increase. Instead, Army evaluators found that it actually slowed the pace of the battle as it created an information overload for leaders and commanders at all levels.

5. Loss of Deterrence

While many agree that technology will give the US military a decisive edge in future conflicts, a great concern is the possibility that this will lead to a loss of deterrence. Strategists have proposed that the use of autonomous sensors and weapons systems will lead to an

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[125] Tice, J. (1997, October, 9). The Deep Strike Revolution: Battle Lab Adds Dimension to Warfare of Next Century. Army Times, p.1

"empty battlefield" where there are no soldiers, and the only evidence of the US military is a battlefield upholstered with sensors. If this holds true, how do we deter future enemies? If an enemy is looking for a tank, and all he sees is a clear avenue of approach for attack, this could cause an increase in conflicts. Despite the ability of the US military to prosecute wars more efficiently, we may actually fight more conflicts because the enemy cannot recognize what we have created as being a threat.

6. Spoofing

Each time the United States has introduced tactics and technologies into the military, a cycle of action, reaction and counter-action has taken place. This is referred to as *spoofing*. In the Gulf War, *spoofing* took the form of decoys, which, would present a visual, and infrared signature identical to an actual Scud missile launcher. With UGS, this type of spoofing can be expected to continue and even increase. The UGS used in Vietnam and the Sinai are susceptible to being spoofed by these types of decoys. Currently UGS are being developed by US government Laboratories that will detect Scud missile launchers by counting the number of cylinders of a vehicle engine as it passes the sensor. The UGS will then compare it to the number of cylinders that a Scud launcher has and report a

detection.[126] As UGSs are introduced, one way an enemy might innovate is to produce Scud launchers consisting of non-standard platforms (different engines, number of cylinders). While this would initially foil a sensor, it could be expected to have a positive benefit to the US forces over the long term. The production and employment of non-standard vehicles might make it harder for the enemy to maintain its missile launchers, provide supply parts and train operators in their use.

A second aspect of the spoofing problem is electronic intercept, detection and jamming. If the UGS transmissions are not encrypted the signal could be intercepted, recorded and retransmitted to draw aircraft or forces into an ambush. If a UGS is constantly transmitting, its signal can be traced back to the sensor and the sensor destroyed. Third, if the signal is transmitted over a single channel, the frequency may be jammed eliminating its value. These concerns require a sensor that transmits in short encrypted bursts with some form of a frequency hopping capability.

7. EMP weapons

The United States has based its warfighting doctrine for the future on information superiority. Much of this is

[126] See Trudo, R., Stotts, L. (1997). Steel Rattler. In G. Yonas (Ed.), Peace and Wartime Applications and Technical Issues for Unattended Ground Sensors. Proceedings of SPIE Vol. 3081, 13-20.

based on advances in electronic systems and digitization of information. Ground sensors fall into this same category. One way in which an enemy might try to *level the playing field* is to use an electro-magnetic pulse weapon. EMP was initially discovered as a by-product of a nuclear detonation. When a nuclear weapon detonates as an air burst, its showers a large area with EMP destroying all electronic circuits within the footprint of the detonation. It has been determined that a single 100 Kiloton hydrogen warhead detonated 300 kilometers above Kansas would destroy or disrupt nearly all electronic circuits in the continental United States. [127] Even a low yield nuclear weapon detonated over Iraq during the Gulf War would have had much the same effect. This necessitates that sensors be hardened against the effects of EMP.

8. Bandwidth Overload

Each transmission system (radio, microwave, laser, etc) has a limited bandwidth. Bandwidth is the maximum rate at which the hardware can change the signal to send data. Transmissions such as video require a much higher bandwidth than voice communications. In the Gulf, there were so many different types of communications being transmitted that the military exceeded the amount of bandwidth available. This

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[127] Edwards, S. (Autumn, 1997). The Threat of High Altitude Electromagnetic Pulse to Force XXI, National Security Studies Quarterly. P. 61-80

forced the military to lease commercial satellites in order to meet the demand. This requires that sensors be designed to do a maximum of data processing internal to the sensor before transmitting. This will assist in reducing the amount of bandwidth required. It will also reduce the time required to transmit the detection of a target.

9. Reduced Value of Camouflage

The purpose of military sensors is primarily to find an enemy that is trying to hide. A tactic employed in the hiders vs. finders dynamic has been the use of camouflage to conceal, deceive or disrupt the enemy force. In recent years, the types of camouflage employed by military forces have not changed much since their use in World War II. Military forces continue to use camouflage paint, nets, foliage and other basic methods. A notable exception is stealth technology however, this type of camouflage is largely the domain of the United States. The employment of UGS on the battlefield (in large quantities) has the potential for eliminating much of the value of the basic forms of camouflage. Camouflage paint, nets, or foliage do not eliminate a magnetic, acoustic, seismic, infrared, or other type of emission, which can be sensed electronically. This may drive future adversaries toward an era of decoy

armies similar to what the allies used during the Normandy Deception of World War II.[128]

E. PRESCRIPTION

The final purpose of this thesis is to develop a prescription for the future of UGS. What qualities should be incorporated into each of the seven principles of UGS to achieve precision engagement?

First, the principle of delivery will require both an airdrop and hand emplacement capability to support a variety of mission applications. It will also require a cheap construction cost. This will support the delivery of large numbers of sensors for greater coverage of the battlespace.

The principle of discrimination requires multiple types of sensings, a video/optic capability, reduced range and embedded GPS. First, sensors must be able to discriminate between multiple types of targets and emissions simultaneously to reduce the chance of a false activation. Second, sensors require a video/optical capability. This will enable sensors to discriminate between enemy forces, friendly forces and civilians. Third, the detection range of the sensors should be limited to 500M or less. A reduced range of detection will enable precision targeting and destruction by cluster bomb munitions. Fourth, sensors

[128] Breuer, W. (1993). Hoodwinking Hitler: The Normandy Deception. Westport Conn ecticut, Praeger Publishing.

require embedded GPS technology to accurately determine the location of emplaced or airdropped sensors.

The principle of secrecy requires EMP hardening, a camouflage design and the development of unclassified sensors. EMP hardening is necessary to prevent an enemy from destroying a great number of sensors using an electro magnetic pulse. A camouflage design will prevent an enemy from collecting or destroying the sensors or maneuvering out of range of the sensors. The development of unclassified sensors would enable the sensor information to be shared with a coalition partner and would also enable precision targeting without the fear that discovery of a sensor might compromise a classified technology.

Dissemination has five technical requirements. Sensors must process the maximum amount of data internal to the sensor. This will reduce the bandwidth requirement of the sensors. Encryption is required to reduce the ability of an enemy to spoof the sensor by intercepting or mimicking the sensor transmission. Burst communications should be utilized to reduce the ability of an enemy to intercept and locate the sensor. Frequency hop communication should be used to prevent the enemy from jamming a single frequency preventing the sensor from reporting. Finally, satellite or HF communications should be utilized to enable long range deployment and reporting by the sensors. While satellite

communications are generally preferred, some environments or terrain might mask the ability of the sensor to communicate with a satellite, or the cost of dedicated satellite channels may preclude their use. In these cases, HF communications may provide a low cost alternative.

The principle of fusion requires that military forces be equipped with remote monitors which will allow them to access the sensor data without going through a centralized facility. This would be for both land and air forces to support ground operations and allow attack aircraft to "milk" the sensors for targets. This would enable sensor information to be rapidly fused with other sources of intelligence such as photos and visual reconnaissance by air and ground forces.

The principle of interrogation requires the ability to detect vehicle emissions and radio signals. Both would increase the sensor's ability to determine if a target was killed or survived after an attack by air or ground forces.

The last principle is endurance. This principle requires a battery life span of approximately one-year. This would support protracted operations and reduce the maintenance or replacement requirements of the sensors. It would also reduce the cost of the sensors as they are primarily a single use technology.

Sensor Requirements	Justification
• **Delivery**	
Air/hand delivery capability	Type of mission will require different delivery methods
Cheap construction cost	Supports delivery of large number of sensors for greater coverage
• **Discrimination**	
Multiple types of discrimination	Reduce false positives and enemy decoy ops
Video/optical capability	Discriminate between enemy/friendly/civilians
Limit detection range to 500M or less	Enable accurate targeting and destruction by CBU
Embedded GPS technology	Enable accurate position location of air dropped sensors and enable detection of sensors collected/moved by enemy
• **Secrecy**	
EMP hardening	Prevent destruction by enemy EMP weapons
Camouflaged design	Prevent enemy from collecting/destroying sensors
Unclassified sensors	Enable sharing of intelligence and technology w/coalition forces
• **Dissemination**	
Max onboard data processing	Reduce bandwidth requirements
Encryption	Reduce ability of enemy to spoof sensor
Burst communications	Reduce ability of enemy to intercept and locate
Frequency Hop communications	Prevent enemy from jamming communications
Satellite/HF communications	Enable long range deployment and reporting by sensors
• **Fusion**	
Equip forces remote monitor	Enable rapid dissemination and fusion of intelligence with other intelligence information
• **Interrogation**	
Vehicle emission detection	Improve BDA through detection of "live" targets
Radio signal detection capability	Improve BDA
• **Endurance**	
Battery life span of 12 months	Provide endurance for protracted operations, reduce maintenance requirements

Table 5.1 Prescription for UGS

F. CONCLUSION

Unattended ground sensors have primary applicability in operations requiring near real-time detection and targeting of perishable targets. They provide focused, tactical, combat information, and the granularity necessary to detect individual soldiers, tanks, and Scuds in a variety of environments. Their capabilities fill requirements in peace and war, contingency operations and protracted conflicts. UGS also support both offensive and defensive applications. If the US military invests now, UGS have the potential of complementing or substituting for air and space systems at the tactical level. This investment in UGS will enable the US military to fill the current sensor gap and achieve *precision engagement*. This is a cumulative strategy, which requires a transition from the big and the few toward the small and the many. In this way, success is defined by a quantitative measure of effectiveness (MOE). The MOE is the quantity of targets detected divided by the number destroyed.

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